UN SDG Assessment Methodology and Guideline

Version 1.01

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The UN SDG assessment methodology supports the screening of research projects' contributions to the UN Sustainable Development Goals (SDG). It has been developed by the Quantitative Sustainability Assessment Group at the DTU Department of Technology, Management and Economics (DTU Management).

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CONTENT

INTRODUCTION

The purpose of the methodology and guideline is to **support a <u>semi-quantitative</u> evaluation of the contribution that a research project can have to a sustainable development** through the 17 UN Sustainable Development Goals (SDG) and their underlying Targets[1]. The SDGs are indicated in the figure on the front page (Source: www.un.org). They altogether address social, economic and environmental dimensions of sustainability.

The developed methodology is inspired by the GHG Protocol's "Project Protocol" standards[2] (also: ISO14064-2:2006 and ISO14064-2:2019[3]) and Life Cycle Assessment standards (ISO14044:2006[4]). Much wider scopes are considered in the methodology as it covers all sustainability dimensions (not just greenhouse gas emissions) and any project that may reach out to systems at societal level.

The methodology comprises 5 main phases, each including a number of steps. Figure 1 illustrates those phases and their interactions, which include some iterative loops in order to focus and strengthen the application of specific phases and steps.

- Phase 1: Defining application(s) of the research project at societal level
- Phase 2: Scoping the assessment
- Phase 3: Inventorying effects from project application(s)
- Phase 4: Evaluating the contributions of the application(s) to SDGs
- Phase 5: Interpreting the assessment results

The theoretical foundation of these phases is explained and illustrated with examples in this methodology description. The application of the methodology to an illustrative concrete case study of different nature is detailed thereafter to provide a guidance on how to follow the different phases and steps of the methodology in practice.

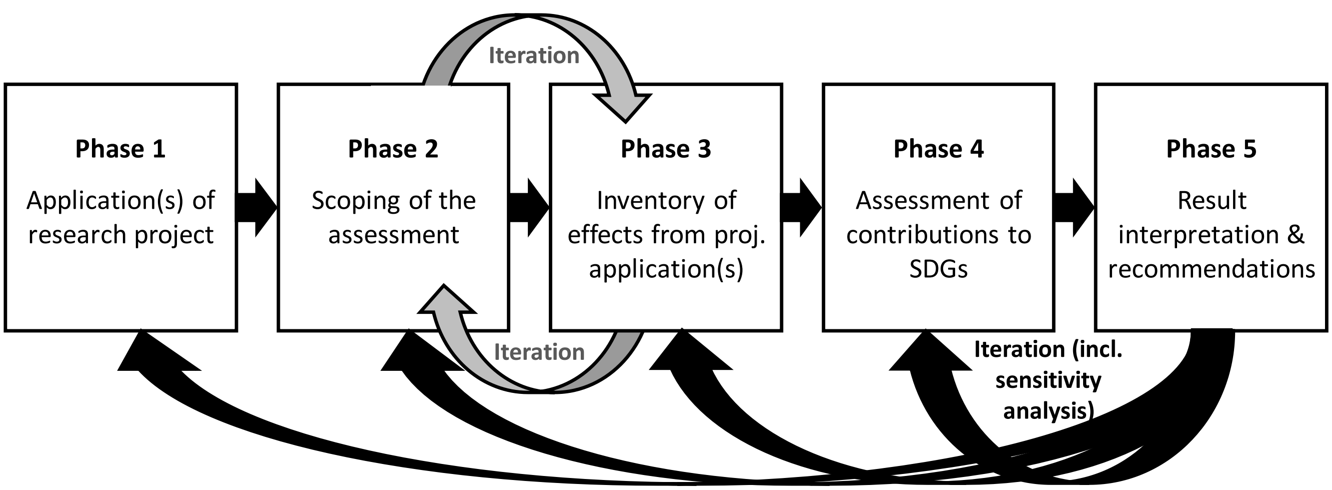


Figure 1. Phases and flow of the UN SDG Screening Assessment Methodology.

[1] UN, 2015. Transforming Our World: the 2030 Agenda for Sustainable Development. United Nations Publishing, New York, NY, USA.
[2] The Greenhouse Gas Protocol, 2006. The GHG Protocol for Project Accounting. WRI/WBCSD, Washington, DC, US. ISBN 1-56973-598-0.
[3] ISO, 2019. Greenhouse gases — Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements (ISO 14064-2:2019). ISO, Geneva, CH.
[4] ISO, 2006. Environmental management – life cycle assessment - requirements and guidelines (ISO 14044:2006). ISO, Geneva, CH.

METHODOLOGY

Each of the 5 methodological phases are introduced and described below.

1. PHASE 1: Defining application(s) of the research project at societal level

The aim of the first phase is to clarify the goal of the SDG screening assessment – what is it that you need to assess the sustainability implications of? To this end you need to take an outside-in view on the research project (termed just "project" in the following for simplicity): what are its potential applications in society? A project can result in a concrete product or technological solution, but may also be a more basic scientific research project that is anticipated to lead to a practical application sometime in the future or just advancing scientific knowledge in a specific domain. To judge positive or negative contributions to a sustainable development, one needs to think of the expected outcome(s) of the project and translate it into a concrete application in socioeconomic systems.

A project may lead to replacing existing technologies with new ones, but it may also lead to introduction of technologies which did not exist before, and some of these may even create new needs in the society, new demands in the market. Some projects may have several possible applications and ideally, they should all be considered in order to reflect the potential impacts of the project outcomes on society and environment (i.e. its contributions to meeting the SDGs). Prioritization may be done, however, to simplify the task.

This prioritization can be done at 3 levels:

- **Type of applications**: the primary focus of the assessment should be on the application(s) resulting from the project outcomes that has/have the highest probability/ies to enter the market and/or with the largest potential impact on the SDGs (society or environment).
- **Geographical and/or activity scoping**: to make the assessment more manageable, it may be useful to delimit the scope of the application, for example to a specific country, region or sector. For example, if a new generic organizational structure in companies is developed through the project, the assessment could be limited to studying the impact on a specific sector in a given region. The assessment results obtained with the thus-limited scope can then be scaled up to a global scale at later stage in the assessment (see Phase 4). As for the type of applications, the combination of probability and impact should guide the delimitation to focus on specific sectors/regions.
- **Time horizon**: The temporal range of the application is important to evaluate, as the applications may be associated with immediate vs. delayed implementation (e.g. technology developed today may show potentials much later) or be relevant over a short vs. long period of time in society (e.g. some technologies can become rapidly obsolete, while others can become keystone for future technology development). The evaluation of the contribution of a project to sustainable development should ideally have a long time horizon to avoid that potentially important impacts far into the future are ignored. We opt to primarily focus the assessments on effects up to 2030 by default, but possible important effects beyond that time should also be noted. This choice of a time horizon up to 2030 is motivated by (i) aligning the time horizon of the assessment with the 2030 SDG Agenda, and (ii) keeping the assessment within a reasonable time frame to avoid the uncertainties associated with development of society and central technologies in a longer time perspective.

Our ability to predict which application(s) will actually take place and to what extent they will be effective is, however, limited. Our choice of considered application(s) may be accompanied by large uncertainties and by others regarded as arbitrary; it is therefore important to document them transparently, arguing for the different assumptions made. This can be supplemented by a sensitivity analysis to test some of the alternative applications and examine how differently they may affect the contribution of the project to the SDGs. The sensitivity analysis also supports the iterative approach integrated in the methodology, where it is recommended to revisit and refine the assessment in each of the methodological steps at least once in the light of the findings from having gone through all the steps a first time.

Identifying the main application(s) of a research project, along with documenting potential limitations in the geographical, activity and/or temporal scoping, is the main outcome of the goal definition. Examples of projects, potential applications, and selected main application(s) are provided in Table 1.

Table 1. Examples of goal identification for different projects.

Project	**Potential application(s)**	**Main application(s)**
Project developing new electrolyte characteristics to increase storage capacity in Li-ion battery technologies.	The developed technology could replace existing Li-ion batteries in various products, e.g. electronic products, electric vehicles (EVs), etc.	Application in EVs is selected as main application due to its large market potential and increasing shift towards EVs in transportation sector.
Project building new predictive models for material appearance. [a]	The new models for enhanced rendering of material appearance could replace existing models, which are used currently as post-processing / corrective steps in manufacturing (e.g. 3D printing).	Application to 3D printing is considered as it is increasingly relevant and predicted to have growing use in many manufacturing processes.
Project developing concepts and methods to identify, quantify and reduce complexity in industrial companies (through all operations). [b]	Implementation of the developed concepts and methods in companies could replace or complement existing structures.	Application to large Danish industrial companies active in the logistics sector is chosen as a main application (assumed more likely to integrate new concepts and methods and with potential strong implications for climate impacts).
Project developing innovative aquaculture process relying on aquaponics (plant and fish symbiotic ecosystems).	Potential replacement of existing systems for supplying (i) agricultural products, and (ii) fish (other aquaculture systems, fisheries).	Both applications for agriculture and fish production can be considered as main applications (food sector applications). Application to Europe is considered (to limit the market scope)
Project developing miniaturized, non-invasive technologies that can track all key health metrics (heart, tensions, key organ activities, etc.)	Sensors to take key health measures that can be used by medical sector as well as by individuals (daily use/monitoring).	Application as smart watch, which can be worn by individuals (hence substituting conventional watches) is considered.

[a] Project topic inspired from a PhD project conducted at DTU Compute by Andrea Luongo

[b] Project topic inspired from a PhD project conducted at DTU Management Engineering by Alexandria Moseley

2. PHASE 2: Scoping the assessment

The objective of the scoping phase is to identify and map all activities and processes affected by the project application(s), as defined in Phase 1. To do so, two virtual situations are defined: one is the world with the project applications – and their consequences on society and/or environment; the other is the world, where that application would not have occurred (i.e. the project did not exist or did not yield any implementable results). The latter situation is referred to as the "baseline system" while the situation with the application can be referred to as the "new system" (see also Clarifying Box 1).

Clarifying Box 1. One baseline or several possible baselines?

It is important to understand that, in reality, there is only one baseline and then several possible "new systems" depending on which application(s) is selected in the goal definition. The baseline is the same no matter what applications are considered because it is defined as the world without the project and its applications. In our methodology, the definition of the baseline can be application-dependent, but only because we refine/limit its boundaries to the affected activities/processes, which may be altered depending on the selected applications.

Phase 2 includes two steps, aiming at defining the assessment boundaries of the baseline and new systems, respectively. In general, both the new system and the baseline fulfill the same functions or services to the society, albeit with the use of different technologies or approaches (replacement or existing products or technologies with improved ones). In some rare cases, innovations may however lead to creating new needs rather than just fulfilling existing needs in a new way (e.g. invention of a new cure). In such cases, there is no alternative technology, product or service, which can be replaced, and the baseline and new system fulfil different functions or needs in the society. The identification of the functions or needs of the project applications in the society can provide a starting point to identify the concerned activities (see also Clarifying Box 2).

Clarifying Box 2. Is there functional equivalence between the baseline and the new systems?

Because the baseline and new systems are broadly defined (up to entire world) and can be regarded as parallel trajectories of how the world may evolve, there may not be functional equivalence between them. Systems may have different functions responding to different needs. Let us take the example of smartphones, so comparing a world with smartphones and a world without smartphones. Smartphones enable the function of calling/texting someone, like conventional mobile phones, and additionally allow access to advanced features normally provided by a computer (e.g. internet access, etc.). Yet, the deployment of smartphones on the market led to substituting conventional phones but did not lead to any decrease in use of computers. A new need corresponding to the multi-functionalities offered by smartphones (in particular the computer functions now integrated into the phones), and not least the possibility to be 'on-line' 24-7 was created, fostering the development of the social media with very wide-reaching implications for society and other technology development. In the baseline system, conventional phones – with less functionality – could still be in use.

Step 1. Delimiting the assessment boundary of the baseline system

For the baseline, the delimitation of the assessment boundary starts by considering the entire world and then refining the scope boundaries to only include existing products, technologies, activities or services that the project application (from Phase 1) can potentially replace and/or impact. For example, if the defined project application is an improved electric vehicles (EV) technology, the baseline boundary could be scoped to the current transportation systems and its predicted operations without that new technology (with possible geographical and temporal limitations defined in Phase 1, e.g. time horizon up to 2030). Other systems that interact with the transport systems, and may be impacted by them and/or impact on them, should also be included. For example, electricity supply systems are interconnected with transport systems wherever EVs are involved, hence these should be included as part of the baseline. When identifying and defining the assessment boundary of the baseline, one seeks to cover all activities that may be directly or indirectly impacted by the application, and leave out those activities that are not.

To ensure comprehensiveness in the mapping of all activities, it is recommended to adopt a life cycle perspective, and include in the assessment boundary all upstream and downstream processes that may be dependent on the identified activities impacted by the project applications. A definition of the life cycle perspective is provided in Clarifying Box 3. Clarifying Box 4 additionally defines what processes are in the context of a life cycle perspective.

Clarifying Box 3. What is the life cycle of a product or a service system?

The life cycle consists of the entire value chain, including manufacturing, use and end-of-life processing of a product or technology. It comprises all processes that are needed for the system to operate and fulfil its functions. To make the life cycle more legible, these processes in a life cycle are often grouped into four life cycle stages, namely raw materials extraction, production, use and recycling & end-of-life. Note that there could be several cross-cutting or intersecting life cycles depending on the application considered. For example, for electricity from fossil fuels, one can consider the life cycle of the power plant, which interacts with the life cycle of fuels during its operation/use (see Figure 2).

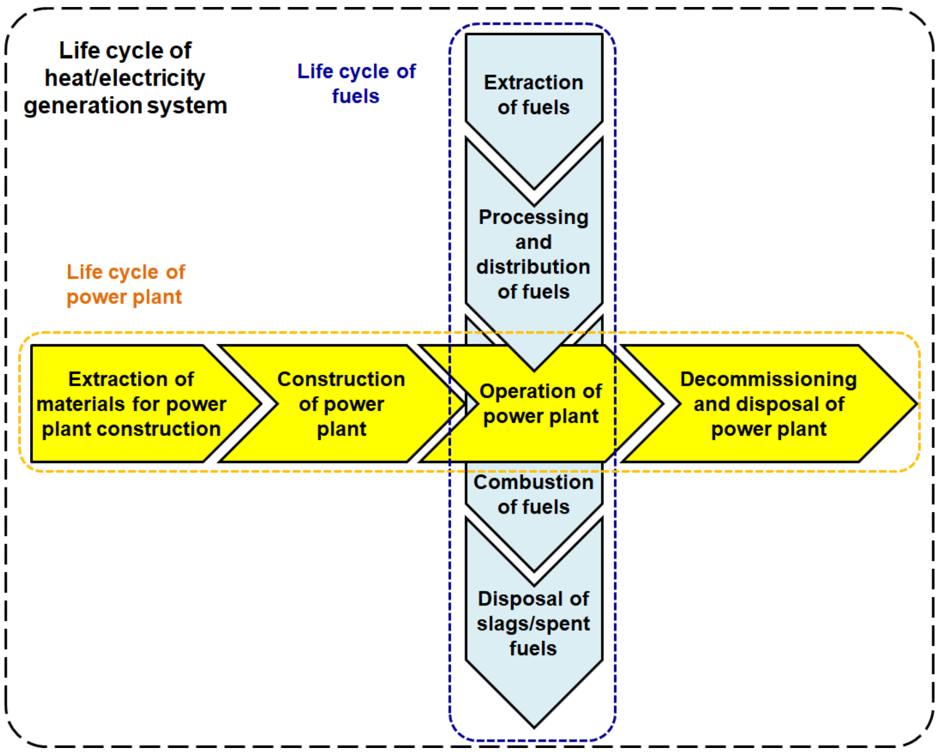


Figure 2. Example of life cycle of electricity generation system, with illustration of the four life cycle stages (raw materials extraction, production, use/operation, recycling/disposal). Note that raw materials extraction and production may also be combined in one stage. Source: Laurent et al. (2018)[6].

The life cycle perspective is a way to ensure that a systemic and holistic approach is applied in the assessment, and that no important aspect or relevant processes affected by the application is overlooked. Hence, when mapping the baseline system, differentiation between the four life cycle stages, i.e. raw materials extraction, production, use/operation and end-of-life, should be done. For example, the main processes in the life cycle of transportation systems based on cars are related to the extraction of raw materials (e.g. mining of metals and crude oil), the manufacturing of the car body and power trains, the production and combustion of fuels and lubricants, the waste management processes including recycling of steel, etc.

[5] Laurent A., Espinosa N., Hauschild M.Z. 2018. *LCA of Energy Systems* (Chapter 26, pp. 633-668). In: *Life Cycle Assessment: Theory and Practice* (Eds. Hauschild M.Z., et al.). ISBN 978-3-319-56475-3. Springer, Dordrecht, NL.

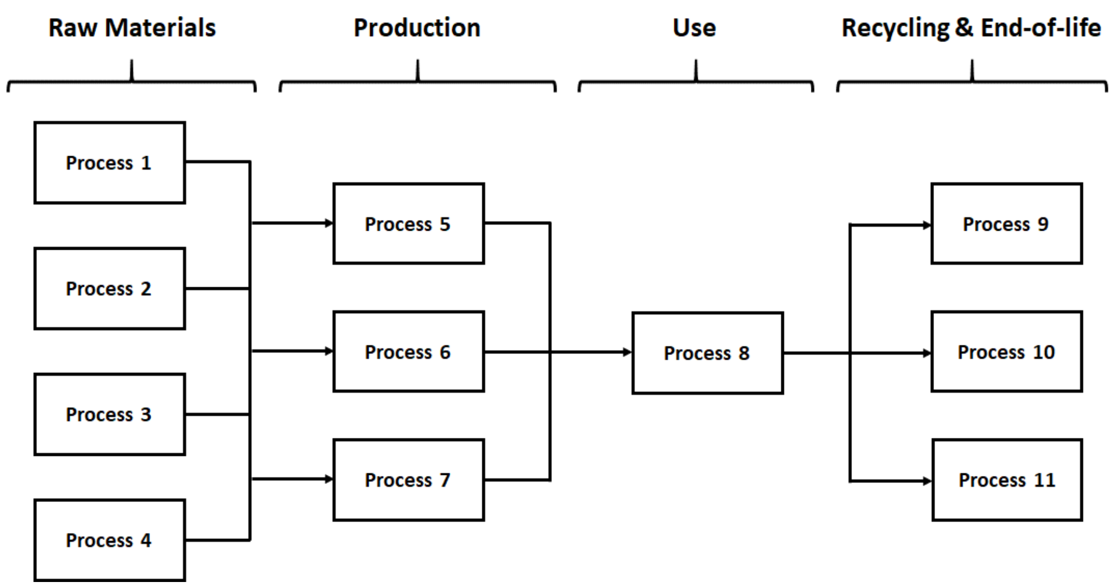
Clarifying Box 4. What are processes in a life cycle?

A process is a physical activity, a building block, of the life cycle[6]. For example, it can be the refining of crude oil, or the assembly of a smartphone from its different components or the waste management of an amount of municipal waste. In the SDG context, main processes are those processes which contribute most positively or negatively to SDGs of the baseline. For example, the main processes in the life cycle of transportation system based on cars are related to the extraction of raw materials (e.g. metals or crude oil), the manufacturing of car body and power trains the production and combustion of fuels and lubricants, the waste management processes including recycling of steel, etc.

The life cycle of a product, technology or activity can be represented by a few highly-aggregated processes (e.g. 'production of engine') or several hundreds of processes, depending on how detailed and accurate one aims to be. Listing all detailed processes in a life cycle is rarely practical because the number of activities is enormous, even for simple products or systems. To improve precision, it is essential to apply the highest resolution to the modelling of those parts of the life cycle that contribute most to the overall impacts from the life cycle. Some of the identified activities and processes may thus be disregarded if they are shown not to be significantly impacted by the project application (little changes expected).

Identifying and gauging the significance of these effects of the project applications is part of Phase 3 (see below), which is a reason why we recommend that *Phases 2 and 3 be done in iteration* (see Fig. 1 in Introduction), so the baseline scoping can be iteratively adjusted not to be too broad (= including activities not impacted or insignificantly impacted by the project application) or too narrow (= omitting relevant activities). Eventually, the outcome of Step 1 is a life-cycle-based overview or mapping of the main activities in the baseline, i.e. those anticipated to change from the new system implementation and thereby contribute positively or negatively to the SDGs in a non-negligible way. Figure 3 (which is the concrete outcome of Step 1) illustrates a conceptual baseline system life cycle with its main processes. If there is uncertainty as to how important some processes are, it is recommended to include them in a first iteration. Such uncertainty may be alleviated through the iterative conduct of Phases 2 and 3, and lead to some of them being flagged as "main processes" while others could simply be removed.

Figure 3. Conceptual example of the life cycle of a baseline system, indicating main processes that are needed to fulfill a given function or service, grouped into four life cycle stages.



[6] Bjørn A., Owsianiak M., Laurent A., Olsen S.I., Corona A., Hauschild M.Z. 2018. *Scope definition* (Chapter 8, pp. 75-116). In: *Life Cycle Assessment: Theory and Practice* (Eds. Hauschild M.Z., et al.). ISBN 978-3-319-56475-3. Springer, Dordrecht, NL.

Step 2. Delimiting the assessment boundary of the new system

In situations, where the new system fulfils the same functions or needs in the society as the baseline, the assessment boundary of the new system should overall be identical to that of the baseline in the type of activities or sectors included, although specific processes may differ between them (e.g. different manufacturing processes, different synthesis pathways for a chemical, few new specific processes, etc.). Figure 4 illustrates how the new system life cycle should be described with indications of the differences compared to the baseline system life cycle. This display of the new system supports the conduct of Phase 3 and should also be iteratively refined after looping the Phases 2 and 3 (representation in Figure 4 can be regarded as the final version after iterations of Phases 2 and 3).

In the rare cases, where the two systems fulfil different needs/functions, the baseline (prior to removal of insignificant activities) is simply the whole world without the new application (see also Clarifying Box 1), as it evolves from now into the future (e.g. until 2030), while the new system can be delimited as the baseline system complemented with the additional activities triggered by the project application in society. To map the activities within such a new system boundary, we recommend to first identify the main sectors that the new application can impact or interact with (e.g. electronics in the example of smartphones, pharmaceutical sector in the example of new drugs, etc.) and map the key processes or activities in the life cycle of those to add them to the mapping of the baseline (done in Step 1).

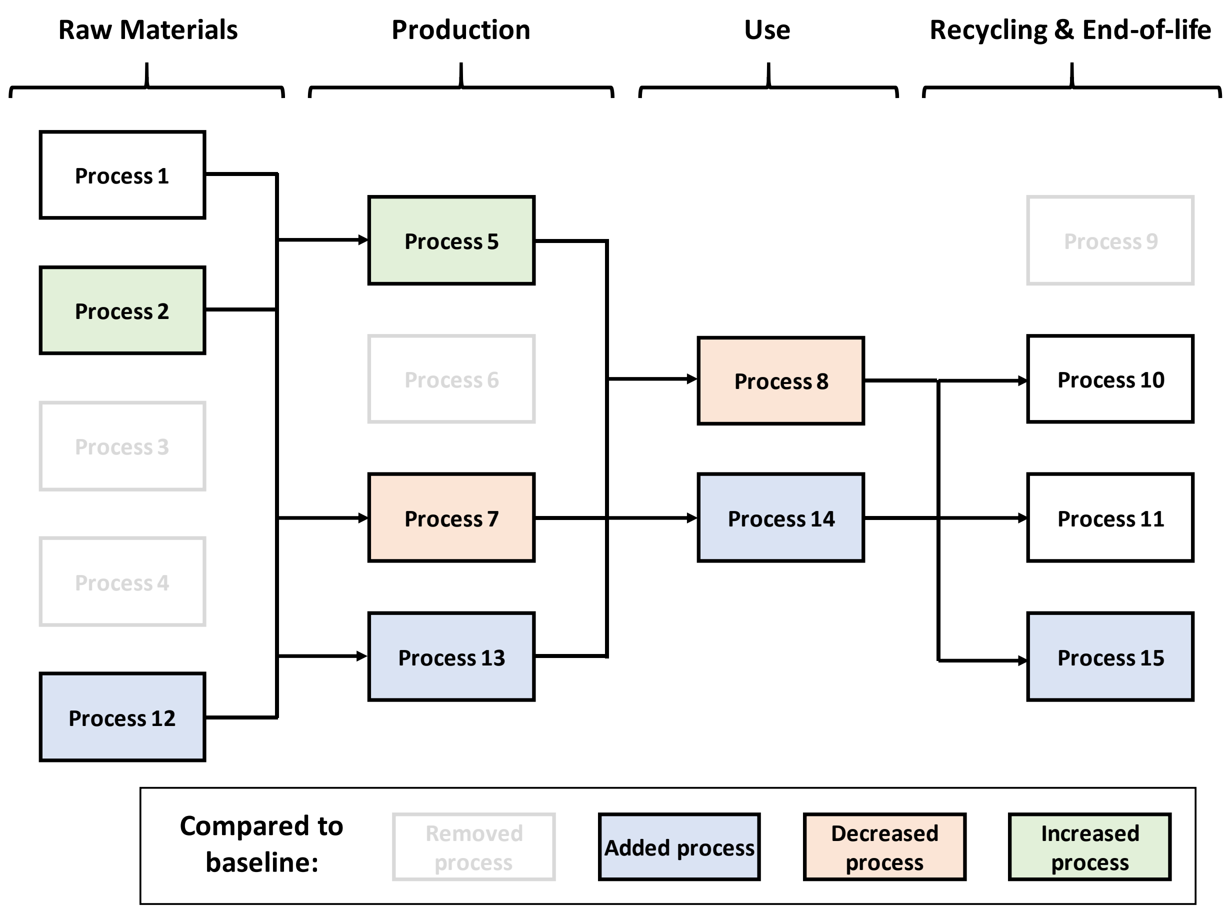


Figure 4. Conceptual example of the life cycle of a new system, indicating main processes that are needed to fulfill a given function or service, grouped into four life cycle stages. When possible, removed processes (light grey) and added processes (blue) compared to the baseline system (see Figure 3) can be displayed as well as processes with decreased (orange) or increased (green) intensities.

3. PHASE 3: Inventorying the effects from project application(s)

The “effects” are changes in activities or processes that the application brings to the baseline (thereby transforming it into the new system). Altogether, the effects therefore express the differences between the baseline and the new system. They can be of very diverse nature: physical or non-physical. Three types of changes in physical processes can exist: (i) introducing new processes to the baseline, (ii) removing some processes from the baseline, and/or (iii) altering existing processes in the baseline to reflect increased or decreased demand for these processes. These physical changes should be visible when comparing the mapping of the baseline (Step 1 in Phase 2) with that of the new system (Step 2 in Phase 2), since they constitute the differences between the two. Non-physical changes can be many-fold: economic (e.g. changes in economic growth), social (e.g. change in consumer behavior), ethical, etc. (Figure 5).

Effects may occur in any of the four stages of the system life cycle. The objective of Phase 3 is to identify all these effects and position them across the four life cycle stages, so as to later be able to evaluate their overall contributions to SDGs (in Phase 4).

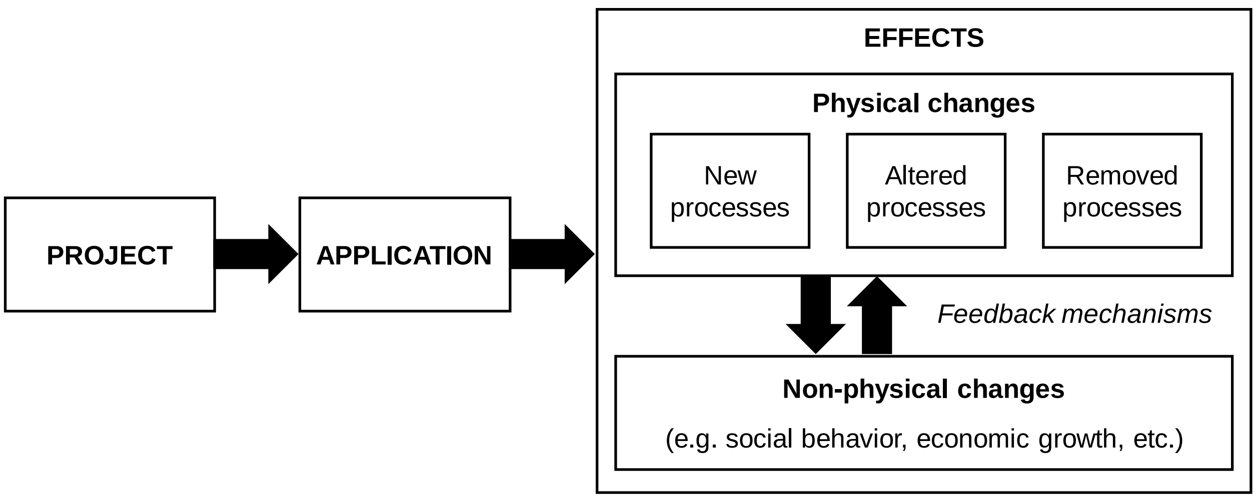


Figure 5. Different types of effects of a project application.

Clarifying Box 5. Baseline, effects and new system: where to start your thinking?

You typically know two things: the current situation and your project. The former knowledge can help you define the baseline, which is the evolution from the current situation, without any application of the outcomes of your project. Now, your insights into the project and the possible outcomes should enable you to estimate (or guesstimate ☺) what your project application may look like and, more importantly, what it can bring as potential advantages and drawbacks, benefits for and negative impacts on society, economy and/or environment. These potential changes introduced to the surrounding world is what we refer to as “effects”. They are all changes in the situation described by the baseline that will occur as consequences of the application of your research outcomes. Taking the baseline and accounting for all these changes will result in a new state, which we refer to as the “new system”. This is why the methodology takes you to identify and define the baseline system in Phase 2, and thereafter identify the effects in Phase 3 in an iterative manner.

We distinguish between direct and indirect effects to facilitate the identification of all effects. Some effects may however be difficult to flag as direct or indirect and here, we recommend to select one of the two categories and document justifications for it. Since the distinction between direct and indirect effects is not carried over to the evaluation phase (Phase 4), the classification has no further implications on the evaluation results. You should consider it as a way to inspire and structure your identification of the effects.

- ***Direct effects.*** The direct changes from implementing the application in society are defined as "direct effects". In applied science projects, they are typically intended effects, reflecting the purpose of the project and its application. They tend to be limited to the main products, technologies or sectors targeted by the application.
- ***Indirect effects.*** The indirect effects are very often unintended and are the consequences of the application implementation on other products, technologies or systems than the systems targeted by the application.

An example using the introduction of bioethanol as automotive fuel to illustrate the distinction between the two types of effects is provided in Table 2. Note that in this example, many processes of the baseline will not change as a consequence of introducing the intended application because they are irrelevant to the application or unchanged by its implementation, and will thus remain the same in the baseline system and the new system. For example, existing gas stations may be used to enable refueling with the new bioethanol blend.

Clarifying Box 6. Direct and indirect effects from a project application.

The project application may have a number of effects on environmental, societal or economic spheres, which will differentiate the new system from its baseline. A project with no obvious concrete application will lead to the definition of a new system nearly identical to its baseline: the only effects will be direct and relate to the graduation of the PhD student; they will mainly consist of the individual development of the PhD student him/herself (higher education, well-being, marginal increase in qualified labor on the overall market) and to increased scientific knowledge. In contrast, a project leading to discovering a ground-breaking technology may lead to important differences between the baseline and the new system. For example, if we retrospectively assume that a PhD project led to the discovery of penicillin, its deployment in society for medical use can be identified as its main application. The baseline would be a world evolving without penicillin while the new system would be defined as a world with it. The (intended) direct effect of the project application is to treat infections (now rendered possible in the new system), which will then reduce morbidity and mortality in the population. As part of Phase 2, a number of processes in the biochemical and medical sectors would have been identified: some processes would be newly-created processes (e.g. new synthesis pathway for penicillin at commercial scale), while others would be altered processes (e.g. need for increased production of an already existing agent for the penicillin production; more transportation needs or more specific materials required). Those can still be considered direct effects. A number of indirect effects would also occur: the large demand for the cure calls for important production efforts, which leads to job creation and new business opportunities for the biochemical industry, and increased user support, like more doctors to handle the treatments. At the same time, as a consequence of easy access to the cure and the generally-better health of the population, people start having longer life expectancies and population tends to increase, leading to more consumption and production with all its associated benefits and impacts for society, economies and environment (e.g. more economic growth, more damages to natural resources, etc.).

Table 2. Example of direct and indirect effects from new bioethanol fuel development (non-exhaustive)

Application	Direct effects	Indirect effects
A project developing bioethanol used as automotive fuel, with application leading to replacement of gasoline made from petroleum hydrocarbons with bioethanol to reduce GHG emissions from combustion	**Physical** Additional demand for biomass (i.e. new or altered existing processes), increased industrial production capacity for fermentation of sugars generated from the biomass and distillation of the resulting bioethanol (i.e. altered existing processes, with increased capacity), development of new logistic pathways in order to enable refueling of the bioethanol (new processes), as well as reduction in production and use of petroleum products, if substitution is assumed rather than increasing demand for both fuels as market mechanism (altered processes with decreased capacity). **Non-physical** Better conscience from driving a car that has less impacts on climate change	**Physical** Possible shortage of arable land caused by the biomass production if 1st generation of biofuels is considered (i.e. the crops used for bioethanol production could otherwise be used for food production, creating a gap in food supply meaning that additional arable land is needed to meet the demand), leading to conversion of natural ecosystems to farmland. **Non-physical** Potential changes in transport patterns and demands, as people may be tempted to travel more knowing they drive with low-carbon vehicles.

Once identified (and after the required iterations with Phase 2), the identified effects should be assigned to the different life cycle stages, where they occur or where they have their main influences. This is true for both non-physical and physical changes (on the principle of additions, removals or alterations relative to the baseline).

For effects relating to physical changes, this specification should cover processes, which (i) shall be removed from the baseline life cycle, and/or (ii) shall be added to the baseline life cycle, and/or (iii) shall be altered to reflect increased or decreased demand, and/or (iv) which are likely not to change (but with uncertainty as to whether they might enter in one of the previous three categories (i-iii)). The recommendation to also include processes that carry uncertainty as to their changes (i.e. category (iv)) is intended to ensure that all main processes are scrutinized to decide whether they should be discarded from the assessment. Processes entering this category (iv) should be addressed via iterations with Phase 2 to determine whether they should be kept or removed. In case of persistent doubt, a conservative approach can be adopted to retain them until the evaluation phase (= Phase 4), where the uncertainty may be resolved.

In this identification process, it may be helpful to start from the life cycle stage which is the most obvious for a given application. In the bioethanol example, it could be the production or use stage: the main processes listed in Figure 3 and Table 2 should serve as starting points and be iteratively completed where needed. Effects that are non-physical changes should also be allocated to the life cycle stages.

Following application of the above identification and categorization of the effects, we recommend to organize them in a table format like in Table 3: it is an intermediary table, which lists all direct and indirect effects of the application across the different life cycle stages. It still retains processes that are not estimated to change. After the iterations conducted between Phases 2 and 3, the uncertainty of these processes is resolved (i.e. whether they should be considered or not), and a resulting table like Table 4 can be derived. Table 4 can be regarded as the main output of Phase 3.

Table 3. Intermediate table showing direct and indirect effects, highlighting processes and non-physical changes have to be altered (orange: decreased intensity; green: increased intensity), added to (blue) or removed from (grey) the baseline life cycle as a consequence of introducing the new system. Processes with uncertainty as to their alterations/changes are marked in black (still in need of further study).

Raw materials	Production	Use	Recycling & End-of-life
Process 1: possibly no change (uncertainty) Effect 1 (Process 2 to decrease) Effect 2 (Process 3 to remove) Effect 3 (Process 4 to remove) Effect 4 (New Process 12 to add)	Process 5: possibly no change (uncertainty) Effect 5 (Process 6 to remove) Effect 6 (Process 7 to decrease) Effect 7 (New Process 13 to add)	Process 8: possibly no change (uncertainty) Effect 8 (New Process 14 to add) Effect 9 (Non-physical change to add)	Effect 10 (Process 9 to remove) Process 10: possibly no change (uncertainty) Process 11: possibly no change (uncertainty) Effect 11(New Process 15 to add)

Table 4. Direct and indirect effects, highlighting processes and non-physical changes which have to be altered (orange: decreased intensity; green: increased intensity), added to (blue) or removed from (grey) the baseline life cycle as a consequence of introducing the new system. Uncertainties in some processes (see Table 3) have now been resolved: no changes for processes 1, 10 and 11, but increased intensities for process 5 and decreased intensity for process 8, leading to 2 new effects listed in the table.

Raw materials	Production	Use	Recycling & End-of-life
Effect 1 (Process 2 to decrease) Effect 2 (Process 3 to remove) Effect 3 (Process 4 to remove) Effect 4 (New Process 12 to add)	Effect 5 (Process 5 to increase) Effect 6 (Process 6 to remove) Effect 7 (Process 7 to decrease) Effect 8 (New Process 13 to add)	Effect 9 (Process 8 to decrease) Effect 10 (New Process 14 to add) Effect 11 (Non-physical change to add)	Effect 12 (Process 9 to remove) Effect 13 (New Process 15 to add)

4. PHASE 4: Evaluating the contributions of the application(s) to SDGs

The effects identified in Phase 3 (Table 5) need to be linked to all SDGs, which they can affect positively and/or negatively. This is the objective of Phase 4, which is divided into two steps and aims to (i) identify the SDGs that may be affected by the effects, thus connecting the effects to the impacted goals and targets of the UN SDG framework (Step 1); and (ii) characterize in a semi-quantitative way the contributions of each effect to the impacted SDGs (Step 2).

Step 1. Identifying the potential SDGs impacted by the effects

The effects identified in the scoping Phase 3 may lead to positive (e.g. better well-being), or negative (e.g. increase of GHG emissions) contributions to social, economic and environmental dimensions of sustainability. The framework of the 17 SDGs and their 169 targets offers an authoritative specification of what is meant by a sustainable development and can be used for connecting the effects of the new system to positive or negative contributions to sustainable development[7].

Various methods may be used for identifying such connections or linkages, and there is no one-size-fits-all approach. Some effects may have been defined in the scoping Phase 3 with a clear link to SDGs, while others may still require identification of potential consequences for society or environment before it is possible to relate them to the SDGs (see Clarifying Box 7). For example, the main effect of a drug like penicillin to improve human health would have an obvious direct connection to SDG no. 3 ("Good health and well-being"). In contrast, the indirect effects of the increased life expectancy that results from the development of such a drug would require further analysis of what positive and negative consequences this may induce in the socioeconomic systems and the environment. For such analysis, the causality chain analysis may be useful (see Clarifying Box 7). A number of other tools exist that may help link the effects to the different SDGs and targets –see Table 5 for a non-exhaustive selection.

Table 5. Tools and methods to help link identified effects with their impacts on SDGs (non-exhaustive list).

Tool / Method	Short description	Link (accessed 11/2019)
SDG sector roadmaps	Guidance on how to identify possible actions towards SDG at sectors, including establishing current positions, Identify key impact opportunities and action possibilities.	https://www.wbcsd.org/Programs/People/Sustainable-Development-Goals/SDG-Sector-Roadmaps/Resources/SDG-Sector-Roadmaps
Blueprint for Business Leadership on the SDGs	Examples and inspiration for business actions in support of achievement of SDGs.	https://www.unglobalcompact.org/library/5461
SDG selector	Identify which SDG is relevant for the specific business.	https://dm.pwc.com/SDGSelector/
Ramboll SDG Impact Assessment	Evaluation tools to identify the relevant SDGs to individual companies.	https://www.results.dk/un-goals/
SDG industry matrix	Industry specific actions and ideas towards SDGs.	https://www.unglobalcompact.org/library/3111

In the identification of links between the effects and the potentially-impacted SDGs, you should be careful to look for positive as well as negative contributions; it is important to identify both at this stage. The gauging of these contributions (semi-quantitatively) is performed in Step 2, but at this point it is important that no potentially important links to SDGs are overlooked. Therefore, we recommend to

1. Go through all targets systematically and see which ones are relevant
2. Be conservative in including any potential SDGs or targets that might be impacted (positively or negatively) by an effect. During the evaluation and interpretation phases (Phases 4 and 5), negligible contributions are identified and could then be removed in an iterative way.

[7] An authoritative and comprehensive introduction to all 17 SDGs and their underlying targets can be found at: https://www.un.org/sustainabledevelopment/sustainable-development-goals/

Clarifying Box 7. Effects, consequences, SDG impacts and causality chain

Effects are defined as the physical or non-physical changes in activities or processes that the application brings to the baseline system when introducing the project applications (see Phase 3). These effects can be directly connected to SDGs and/or targets (e.g. increase partnerships in a project applications facilitating synergies between industrial players, thus directly connecting to SDG no. 17) or have a chain of consequences on other socioeconomic and/or environmental systems before impacting a specific SDG or target (See Figure 6).

Representing the causality chain as flow charts, as illustrated in Figure 7, can offer a visual way to help the user understand the mechanisms by which an effect (i.e. physical or non-physical change) may lead to environmental, social or economic consequences, and eventually to an impact on one or more SDGs and associated targets.

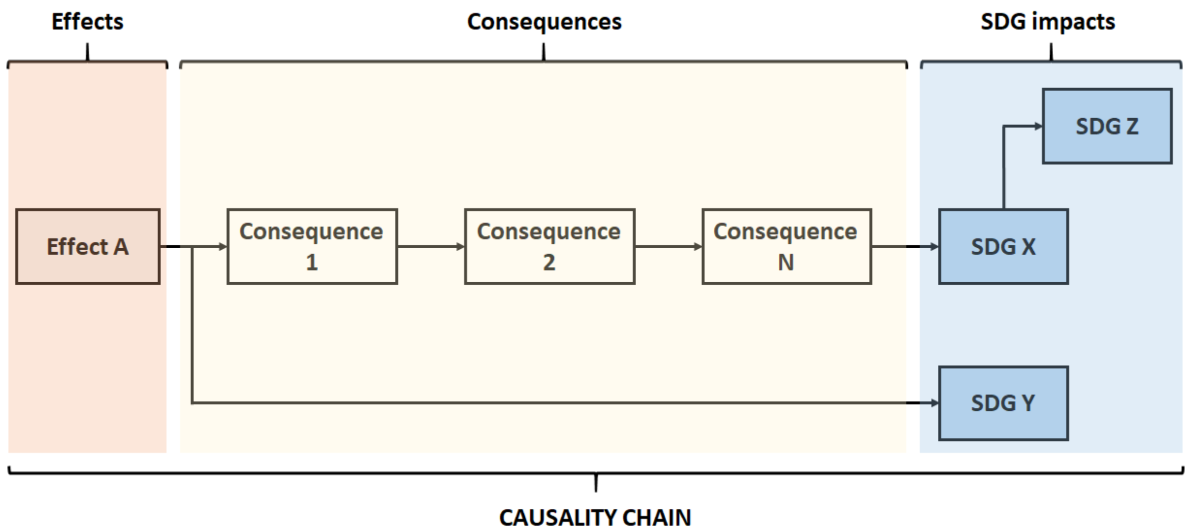


Figure 6. Conceptual causality chain linking effects and SDG impacts

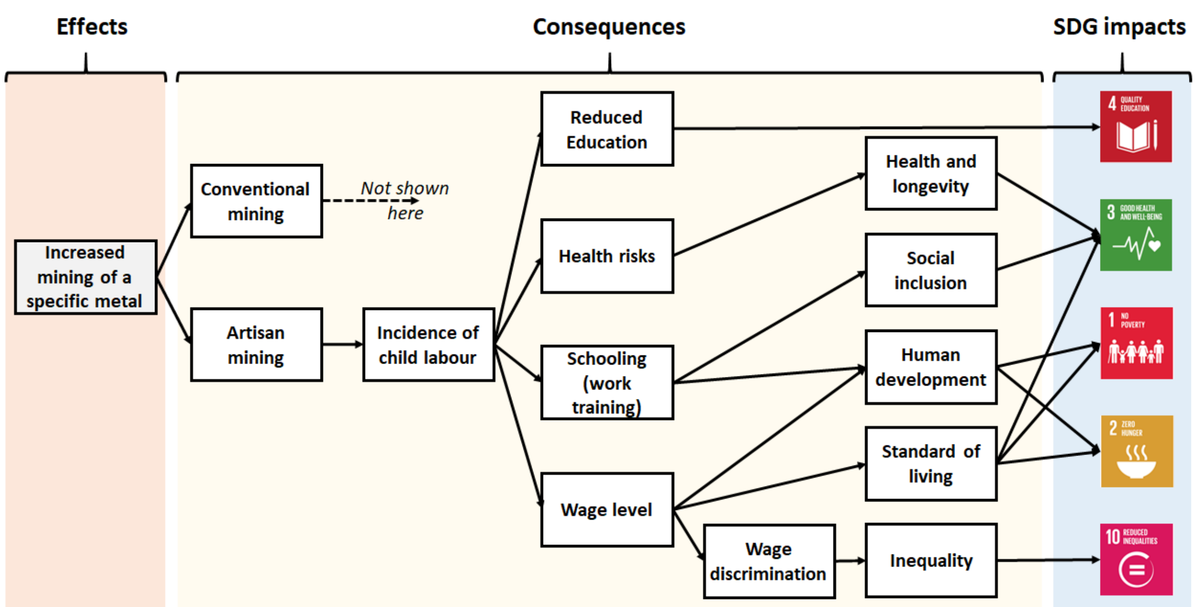


Figure 7. Illustrative causality chain linking increased mining of a specific metal (with focus on artisan mining involving child labor) to SDG impacts.

Table 6 is the main output of Step 1. It summarizes and documents the connections of each effect to the relevant SDGs and targets. Note that numerous interlinkages exist between the SDGs and between their individual targets, meaning that a negative contribution to an SDG X may induce a negative contribution to another SDG Z (e.g. in Figure 5) and counterbalance a pre-identified positive contribution to SDG Z. Such interlinkages should be captured as much as possible in the evaluation. This should be indicated in Table 6 as well, adding additional rows for each interlinked SDG and providing justifications for each interlinkage in the last column). In Table 6, for Effect 1, SDG N_6 is impacted via SDG N_1; likewise for SDG N_8 being impacted via SDG N_2. A number of tools and methods exist to identify these cross-cutting links –some are listed in Table 7.

Table 6. Template of identification of SDG impacted by each effects, along with justifications

Effect	**SDG**	**Target**	**Justification for SDG-Targets impacts**	**Justification for interlinked SDG-Targets impacts**
Effect 1	SDG N_1	Target $N_1.n_1$	## *Justifications* ##	Cross-link with SDG N_6
	SDG N_6	Target $N_6.n_1$	Caused by the impacted target $N_1.n_1$	## *Justifications* ##
	SDG N_2	Target $N_2.n_2$	## *Justifications* ##	Cross-link with SDG N_2
	SDG N_8	Target $N_8.n_3$	Caused by the impacted target $N_2.n_2$	## *Justifications* ##
Effect 2	SDG N_3	Target $N_3.n_4$	## *Justifications* ##	-
…	…	…	…	…

Table 7. Tools and guidance to help identify interlinkages between SDGs and their targets (non-exhaustive list).

Tool / Method	**Short description**	**Link (accessed 11/2019)**
SDG Interlinkages Analysis & Visualization Tool	Identify the interlinkage between SDGs and targets.	https://sdginterlinkages.iges.jp/visualisationtool.html
A guide to SDG interactions	Identify SDGs interlinkages across goals and targets	https://council.science/publications/a-guide-to-sdg-interactions-from-science-to-implementation
Nexus approach for the SDGs: Interlinkages between goals and targets	Identify interlinkages between SDGs and targets.	http://sdgtoolkit.org/tool/a-nexus-approach-for-the-sdgs-interlinkages-between-the-goals-and-targets/

Step 2: Semi-quantitative evaluation of the contributions to SDGs

The evaluation of the new system's contribution to the SDGs can be conducted qualitatively or quantitatively. Quantitative assessment can at this point only be performed for a limited number of targets of the SDGs using dedicated tools or methods that have been developed for specific applications (e.g. specific sectors, industry, etc.). This means that a full quantitative evaluation covering all SDGs is currently not possible. In the present methodology, we propose a semi-quantitative assessment to characterize the extent of the contributions of each effect from the application to the SDGs (also termed "SDG impacts" in the following).

The assessment should consider the following three criteria:

1. ***Direction of the SDG impacts:*** Whether the contribution is positive or negative (or negligible/unknown).
2. ***Likelihood of the SDG impacts:*** likelihood that they will occur based on objective evidence to the extent possible.
3. ***Magnitude of the SDG impacts:*** expected magnitude of the impact based on objective evidence to the extent possible.

Table 8 offers rules of thumb for assessing the likelihood, based on definitions for evaluating climate change risks from the IPCC[8]. As the evaluation of the SDG impacts is a forecasting exercise, the likelihood is dependent on the user's subjective judgement, but it should be based on objective evidence to the extent possible. This is why we recommend a particular care in transparently reporting the assumptions made when assessing the likelihood. In the assessment, the likelihood can be estimated with a numerical value (0-100%) if there is sufficiently robust arguments to back up the estimation, or it can be given as the qualitative statement (i.e. "likely", "possible", "unlikely").

Table 8. Guidelines for evaluating the likelihood of SDG impacts

Likelihood	**Description**	**Likelihood**
Likely	There is reason to believe that the SDG impact will happen as consequence of the effect. For example, production of cars will likely to lead to the increase of chemical pollutants during the manufacturing stage, thus increase the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination (SDG 3).	>67%
Possible	There is some probability that the SDG impact will happen as consequence of the effect. For example, increase of crude oil extraction may lead to pollutants emitted to the water body, soil and air around the oilfield, thus reduce the water quality (SDG 6). However, whether this consequence will happen depends on how the oilfield is managed. Thus it is categorized as possible to happen.	33%-67%
Unlikely	There is a low probability that the SDG impact will happen as consequence of the effect. The impacts for which you cannot determine the likelihood should be categorized here. For example, production of extra electricity due to use of EV may result in increased consumption of natural resources (SDG 12). However, the extent depends strongly on the type of energy source that is used to produce the affected marginal electricity. While fossil energy sources have extensive use of non-renewable resources during the production stage, this is much more limited with renewable energy sources, for example in Denmark. Depending on the energy system in the affected region, the contribution of this effect to SDG 12 may be considered unlikely.	<33%

Relating the SDG impacts to a given situation is necessary to enable benchmarking and appraising the magnitude of the SDG impacts. Two situations/levels should be taken: (i) the project application as defined in Phase 1 (with its specific limitations in terms of types of activity, geographical and activity scoping, and time horizon); and (ii) the entire global perspective, for which the SDGs were primarily defined. In the assessment, we recommend to first conduct the assessment at the level of the project application, as defined in Phase 1. Then, the results and conclusions should be discussed with respect to how they may be altered when upscaling the considered applications to include all possible types of applications (e.g. sensors taking key health measures as in Table 1 considered for smart watch applications, now extended to all applications, incl. medical sector, etc.) and/or the full geographical range of the applications (e.g. from selected countries/regions to entire world) and/or an extended time horizon (e.g. beyond 2030), wherever relevant and applicable. Contributions relative to the total global contributions to the SDG impacts should thus be assessed in this latter case.

[8] Mastrandrea, M.D., C.B. Field, T.F. Stocker, O. Edenhofer, K.L. Ebi, D.J. Frame, H. Held, E. Kriegler, K.J. Mach, P.R. Matschoss, G.-K. Plattner, G.W. Yohe, and F.W. Zwiers, 2010. *Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties*. Intergovernmental Panel on Climate Change (IPCC). Available at <http://www.ipcc.ch>.

Following above recommendations, the magnitude can first be estimated by gauging the impacts that the project application(s) makes on the SDGs and associated targets (level (i) in above), considering if it affects the entire geographical scope of the application (e.g. affecting population in a specific small part of the region or the entire region) and/or the entire temporal scope of the application (long-lasting vs. punctual impacts). An example is a project developing cures for snake bites. If the project applications (= the serum) enables to significantly decrease the mortality rate from snake bites, then it may be estimated to have a large impacts on SDG 3 ("good health and well-being"). Taken in a global perspective (level (ii) in above), the global number of deaths by snake bites should be related to the total deaths in the world to gauge the global SDG impact contributions.

To assist in characterizing the magnitude of the SDG impacts of the considered project applications (level (i)), we propose the use of the thresholds described in Table 9 and inspired from Cohen (1989)[9]. Like for the likelihood, it is possible to estimate the magnitude with a specific value (0-100%) or use the qualitative statements (large-moderate-small-negligible).

Table 9. Guidelines for evaluating the magnitude of SDG impacts (for project applications; level (i)).

Magnitude	**Description**
Large 50-100%	The effect will have a major impact contribution to the SDG-target. For example, if the use of EV increases dramatically in a country with a renewables-based electricity grid mix, this may significantly improve the sustainability of transport system in the city, thus contributing positively to SDG 3 (good health and well-being) or SDG 11 (sustainable cities) with a major contribution.
Moderate 20-50%	The effect will have a moderate impact contribution to the SDG-target. For example, SDG 9 is to Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. Consumers' behavior change or willingness to use EV will promote the development of EV sector, which is considered as a sustainable industrialization with clean and environmentally sound technology. However, the consumer's behavior change may not be the main driving force for the SDG impacts, but still has its large contribution to the SDG, thus the magnitude is considered moderate.
Small 5-20%	The effect will have a minor impact contribution to the SDG-target. For example, the production of EV-specific parts will increase the emission of chemical pollutions, of which a fraction will be emitted to the marine water, thus contributing negatively to the prevention and reduction of marine pollution (SDG 14). However, the share of marine pollution coming from the EV-specific parts is not expected to be significant in comparison with all other industries that emit marine pollution. Thus the contribution of this effect to SDG 14 is considered minor.
Negligible 0-5%	The effect will have no or little impacts on the SDG-target.

The combination of the information from the three criteria is the basis of a semi-quantitative evaluation of the contribution of an effect to a specific SDG-target impact. An Excel-based tool has been developed to make the evaluation – and its documentation – easier to carry out (see attached file). It uses the correspondence Table 10. The likelihood and magnitude can be indicated either quantitatively (numerical values) or qualitatively (e.g. "large", "likely", etc.). Documentation to justify the likelihood and magnitude estimates should also be indicated therein. The resulting table resembles Table 11 (see Excel-based tool).

[9] Cohen J., 1988. Statistical Power Analysis for the Behavioral Sciences. Second edition. ISBN 0-8058-0283-5. Lawrence Erlbaum Associates, New York, US.

Table 10. Scoring system for evaluation of an effect contribution to SDG

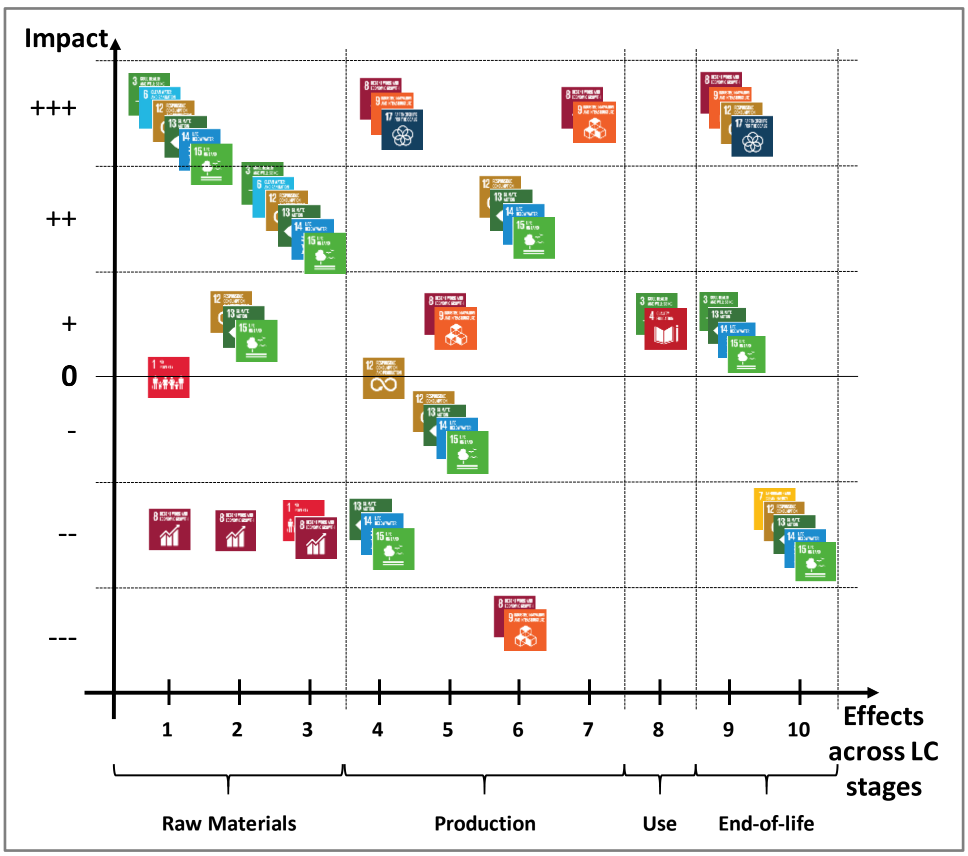
Magnitude/Likelihood	Likely	Possible	Unlikely
Large	+++/---	++/--	+/-
Moderate	++/--	+/-	0
Small	+/-	0	0
Negligible	0	0	0

Table 11. Illustration of SDG impacts evaluation scores of the effects (as in Excel-based tool)

Effects	**SDG**	**Targets**	**Direction**	**Likelihood**	**Magnitude**	**Evaluation score**	**Justifications for likelihood**	**Justifications for magnitude**
Effect 1	SDG N_1	Target N1.n1	positive	likely	large	+++	xxxxx	xxxxx
Effect 2	SDG N_2	Target N2.n2	negative	possible	small	0	xxxxxx	xxxxx
…	…	…	…	…	…	…	…	…

Using the information from Table 4 from Phase 3, which categorizes all effects according to the life cycle stages that they primarily relate to, Table 11 should then be translated into Figure 8, offering a graphical representation of the detailed evaluation of SDG impacts for communication and use in the interpretation (Phase 5). Figure 8 is the main output of the Phase 4.

Figure 8. Illustration of a sustainability assessment profile showing the contribution of a project application to the different SDGs (based on Laurent et al. 2019[10])



[10] Laurent A., Owsianiak M., Dong Y., Kravchenko M., Molin C., Hauschild M.Z., 2019. Assessing the Sustainability Implications of Research Projects against the 17 UN Sustainable Development Goals. Submitted to *Procedia CIRP* (10/2019).

5. PHASE 5: Interpreting the assessment results

Through Phases 1-4, the contribution of a project and its considered application(s) to the SDGs have been identified, categorized in a life cycle perspective and semi-quantitatively assessed. The detailed results of this evaluation, which are represented in the form of Figure 8 enables the user to identify possible hotspots for improvement (i.e. parts in the system life cycle, where large negative contributions to the SDGs are caused) and also reveal trade-offs between SDGs (when the application leads to positive contributions for some SDGs and negative for others). This information can be used in an overall characterization of the contribution of the project to sustainable development (as represented by the SDGs). It is also very useful for identification of improvement needs that may be further analyzed and potentially integrated into the research project.

In interpretation of the results, the following questions should therefore be addressed:

- What are the main sustainability impacts of the implementation of the outcomes of the research project?
- Which SDGs are most relevant for the project, identified as the ones that receive the largest contributions across the life cycle, both positive and negative? Where do they occur, i.e. in which life cycle stage(s) and what causes them?
- Are there tradeoffs between life cycle stages when all positive and negative contributions to SDGs are considered?
- For an individual SDG, are there tradeoffs between effects or life cycle stages so that a positive contribution from one may be outweighed by a negative contribution from another to the same SDG?
- Are there tradeoffs between social (SDG 1-6, 16-17), economic (SDG 7-11) and environmental (SDG 12-15) dimensions of sustainability?

Answering the questions above provides a useful starting point to interpret the results further in terms of potential changes that can be made with regard to the project and its resulting application. Depending on the obtained results, there may be a need for performing a sensitivity analysis, where other applications are tested, where a different scoping is considered, or where the analyses of the baseline and the new system defined in Phases 1 and 2 are revisited and refined to improve the certainty for some of the central assumptions that were made. Such iterations, as illustrated in Figure 1 (in the Introduction section), are fundamental for the effective use of the methodology.

In general, the interpretation phase is project-specific as both the nature of the analysis and its outcome depend on the assumed project application. This analysis should also lead to possible recommendations on how to improve the SDG performances of a specific project application. These recommendations can be divided between *short-term recommendations to stakeholders conducting the project* (PhD students and supervisors to take measures within the PhD project to prevent negative contributions to SDGs during future implementation of the project application) and *long-term recommendations to stakeholders in charge of implementing the project results into the society* (translating the output of the project into concrete applications). To facilitate reaching such conclusions, the following questions may be addressed:

- Where in the life cycle of the application can changes be made so that some of the negative SDG impacts are mitigated?
- What could those specific changes be? Characterize them from a technological or economic point of view (also assessing their feasibility).
- Can any of these changes be anticipated in the PhD project itself so the negative SDG impacts are prevented from happening when the application is implemented?

REPORTING TEMPLATE

The following is a template to report your SDG assessment, documenting its methodological application and results. The report should be concise with an extent of approx. 5 pages plus appendices. Use the appendices to transparently document the assumptions you made on the different methodological steps and the detailed tables to support your results. You may also refer to the illustrative case study as inspiration and guidance on reporting expectations.

1. Phase 1: Considered application(s) of the research project *(ca. 0.5 page)*

- Describe briefly the research project
- Describe potential societal or technological application(s) of the research project and justify the selection of the application chosen for the assessment, including types of activities, geographical/activity scoping and time horizon.

2. Phase 2: Scope of the assessment *(ca. 1.5 page)*

2.1. Delimitation of the baseline system

- Describe and justify products, technologies or services, which are replaced by the main application or, in rare cases, describe which new needs in the society the main application fulfills
- Present the life cycle of the baseline in a figure, in the form of a flow diagram, indicating the main processes (see Figure 3 in the methodology that should be used as template)

2.2. Delimitation of the new system

- Describe and justify products, technologies or services of the new system and/or, in rare cases, describe which new needs in the society the main application fulfills, including specifying the main processes of the sectors that the new application can impact or interact with
- Present the life cycle of the new system in a figure, in the form of a flow diagram, indicating the main processes (see Figure 4 in the methodology that should be used as template)

Recommendation: in both Sections 2.1. and 2.2, report the final mapping of the life cycle of the baseline and new systems, after having gone through the iterations between Phases 2 and 3, so the system life cycle should only include the main activities affected by the project applications (see Methodology).

3. Phase 3: Inventory of effects from the applications *(ca. 1 page)*

Present the main direct and indirect effects of the project application(s) in a table, indicating processes which are either introduced as new to the baseline, removed from the baseline, or altered in the baseline. Also identify and position effects that are non-physical changes (social, economic, ethical, etc.). Justify the effects, potentially using a separate section in Appendix A. Position the effects across the four life cycle stages of the baseline. Table 4 from the Methodology should be used as template.

4. Phase 4: Evaluation of the application contributions to SDGs *(ca. 1 page)*

- Justify the impacts on SDGs-targets for each effect, and the cross-SDG links (Step 1 from Phase 4 in Methodology) in a table that you document in Appendix B. Table 6 in Methodology should be used as template.
- Justify the likelihoods and the magnitudes of the SDG/target impacts, and report the evaluation results of the assessment (Step 2 from Phase 4 in Methodology) in a table that you document in Appendix B. Table 11 in Methodology should be used as template.

Recommendation: To facilitate the reporting of both above points, provide the filled-in tables from the Excel-based tool, which already integrates Table 6 and Table 11 (in separate spreadsheets). The filled-in Excel file is the Appendix B (kept as separate electronic file), hence no need to copy/paste the tables in your report.

- Present the evaluation results in a figure, using Figure 8 in Methodology as a template.

5. Phase 5: Interpretation of the assessment results *(ca. 0.5 page)*

- Describe as a minimum the 3 most important positive and the 3 most important negative SDG impacts of the implementation of the considered project application(s)
- Describe possible hotspots for improvements, potential tradeoffs between SDGs and between life cycle stages and/or components of the new system, and potential tradeoffs between social, economic and environmental dimensions of sustainability
- Provide short-term recommendations to stakeholders conducting the project and long-term recommendations to stakeholders in charge of implementing the project results into the society (See Methodology)

6. References *(no page limit)*

Lists references used in the report.

7. Appendices *(no page limit)*

Appendix A

Detailed documentation behind the identification of effects (Phase 3)

Other necessary documentation for transparent reporting

Appendix B (Excel file)

Excel file with (i) justification of SDG impact and the cross-SDG links (Table 6 as template), and (ii) detailed SDG impact evaluation, incl. evaluation scores and justifications of likelihoods and magnitudes of the SDG impacts

ILLUSTRATIVE APPLICATION OF THE METHODOLOGY:

PROJECT ON NEW BATTERY TECHNOLOGY DEVELOPMENT

This guidance illustrates the application of the SDG assessment methodology to a virtual case study, with a reporting in compliance with the reporting template provided above. For pedagogical purposes, the reasoning in the application of specific phases/steps is documented as boxes (outside the reporting requirements).

1. Phase 1: Considered application(s) of the research project

The project used as a virtual case is taken from one of the examples from Table 1 in the methodology. It focuses on the development of new electrolyte characteristics to increase storage capacity in Li-ion battery technologies. The developed technology could replace existing Li-ion batteries that are in use in many different applications, e.g. electronic products, electric vehicles (EVs), etc.

For the assessment, the application in EVs for car transportation is selected as main application due to its large market potential and the increasing shift towards EVs in the transportation sector in Europe (which is assumed the primary geographic zone of interest for the study). To keep the scope of the study manageable in this example, only the Danish market for use of EVs as passenger cars is considered in the assessment. Sensitivity analyses or further study may be conducted later to expand that scope to the entire European market (or wider) and to also include other types of applications (e.g. electric trucks for freight transport, other transport modes, other applications than transport like electronics, etc.). The time horizon in the assessment is taken as default up to 2030.

2. Phase 2: Scope of the assessment

2.1. Delimitation of the baseline system

EVs are already in use in several European countries to move away from petroleum-based conventional vehicles, which constitute the bulk of the vehicle fleet today and are associated with large emissions of greenhouse gases and air pollutants. Therefore the baseline can be identified as the passenger car transport systems in Denmark with current projections as to the distribution of power train technologies (Internal Combustion Engines (ICE) vehicles, battery EVs, hybrid EVs, etc.) and fuels (e.g. petroleum-based, biomass, electricity). An illustration of possible baseline system is given in Figure 9[11].

Determination of the life cycle of the baseline essentially comes down to mapping the life cycle of the passenger car fleet system, including all its components; this is illustrated in Figure 10.

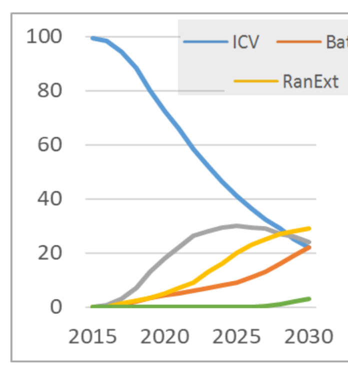


Figure 9. Baseline system evolution up to 2030, with relative decrease of ICE vehicles (ICV) and increase of EVs, i.e. battery (Batt), Hybrid (Hyb), Range-extended (RanExt) and Fuel-cells (FuCell) vehicles (Source: Bohnes et al.[11])

[11] Bohnes F., Gregg J. S., Laurent A., 2017. Environmental impacts of future urban deployment of electric vehicles: a case study of Copenhagen for 2016-2030. *Environ. Sci. Technol.* 51, 13995–14005.

In the life cycle, the raw material extraction stage includes extraction of fossil fuels and mining of metal ores used to produce various components of the car (e.g. plastic parts; steel, aluminum and other metallic parts used to construct the car body and engine/motors; rare earth elements for actuators and sensors; etc.). The production stage primarily includes the manufacture of the different car components and their assembly as well as the production of the infrastructures (e.g. charging stations). The use stage mainly consists of the driving of the car, thus relying on the fuel life cycle, which encompasses extraction and refining of crude oil for petroleum-based fuels and/or production of food crops and non-food biomass for biodiesel or bioethanol, mining of the resources pertaining to the generation of electricity (for EVs), transport and distribution of the fuels or electricity, fuel combustion (for ICE), and waste management of slags from fossils-fueled power plants. Maintenance for the operation of the system (e.g. refueling for gas stations, maintenance of the car and charging stations, etc.) is also part of the use stage. The recycling & disposal stage includes car disassembly and reuse of some components, disposal of liquid hazardous waste (e.g. car battery), shredding of the car, recycling of ferrous and non-ferrous metals, and landfilling of post shredding residue. Waste management of the infrastructures, like charging stations, complete the disposal stage.

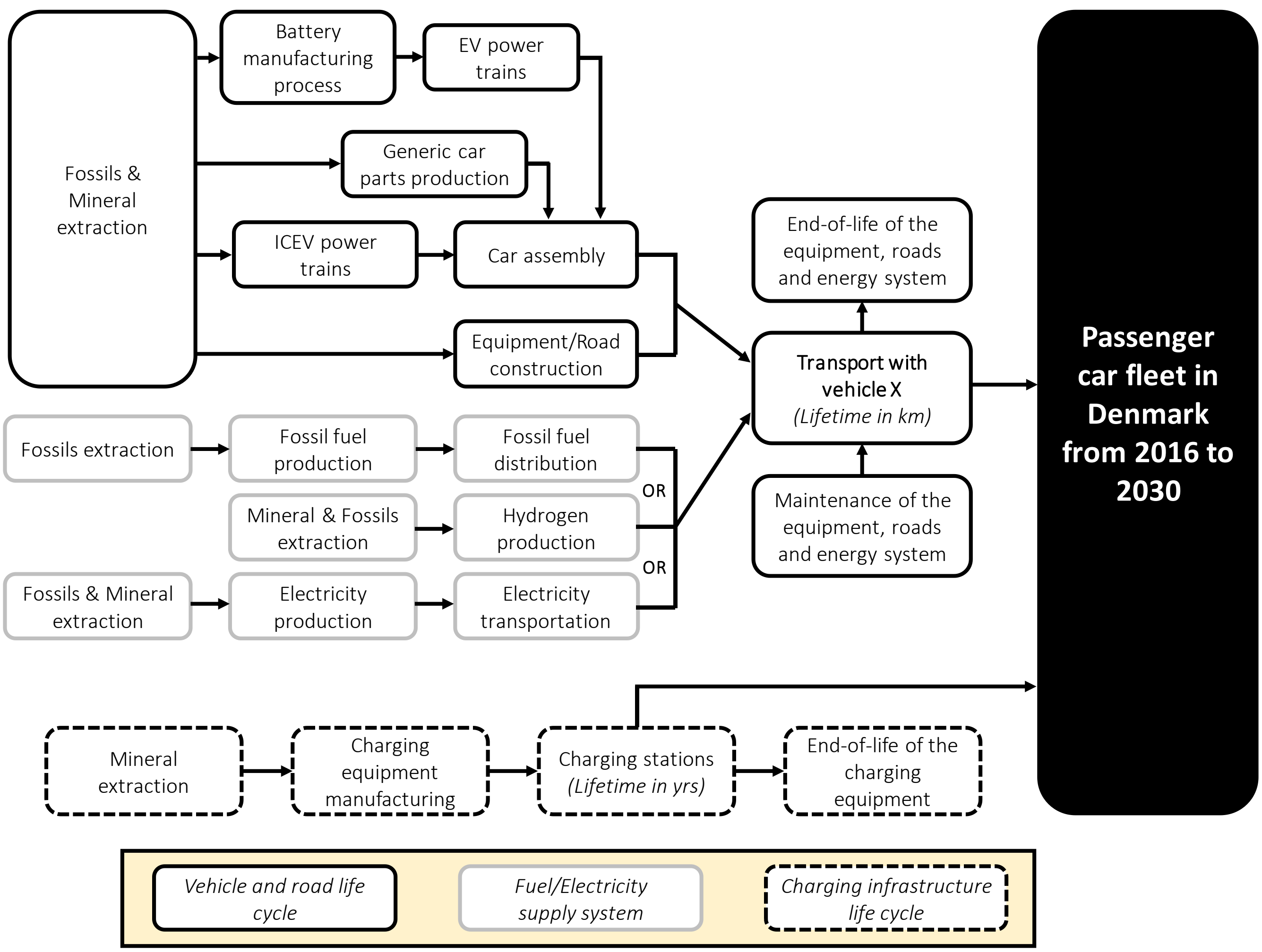


Figure 10. Simplified overview of the life cycle of passenger car fleet in Denmark, as in baseline, showing the main processes in the life cycle of the different components of the fleet system. Based on Bohnes et al. (2017).[12]

[12] Bohnes F., Gregg J. S., Laurent A., 2017. Environmental impacts of future urban deployment of electric vehicles: a case study of Copenhagen for 2016-2030. *Environ. Sci. Technol.* 51, 13995–14005.

2.2. Delimitation of the new system

The project application (= new EVs with improved battery storage, also referred to as "new battery EVs" in the following) could make EVs more attractive to customers (e.g. because of extended range enabled by the new battery technology) and speed up the penetration of EVs on the market, thus leading to a faster deployment of EVs to replace conventional internal combustion engines (ICE) vehicles. This entails different projection scenarios, which are illustrated in Figure 11. The exact performances of the new battery EV is likely unknown or at least uncertain at the time of the project, hence a best guess should be made and documented based on available literature or data found on the application (e.g. market studies, projections, etc.). It is advisable to define ranges of key values or scenarios that can be used later as sensitivity analysis.

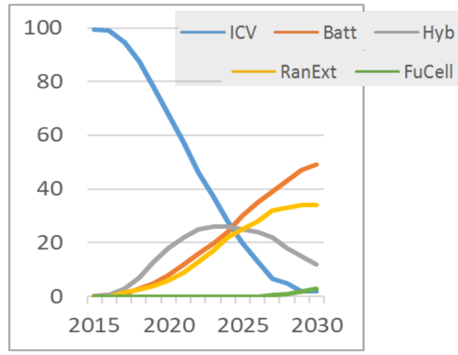


Figure 11. New system evolution up to 2030, with, compared to baseline steeper decrease of ICE vehicles (ICV) and increase of battery EVs (Batt). Hyb: Hybrid, RanExt: Range-extended; FuCell: Fuel-cells vehicles (Source: Bohnes et al.[13])

Several parameters can be influential on the penetration rate of the new EVs with improved battery storage, including production costs, national regulations or incentives (e.g. bans or subsidies to limit or encourage specific technologies), driving habits, adapted infrastructure availability (e.g. charging stations), etc. Many of these parameters are region- or country-specific, meaning that the extent of substituting conventional vehicles with EVs may differ from one country to another. In countries, where substitution will be rendered more difficult because of national conditions, the new system will be closer to the baseline (= little difference since little penetration of new EVs). In contrast, in countries with government incentives and measures facilitating EVs deployment, the difference between the baseline and the new system will be more important. In a potential sensitivity analysis focusing on other countries or entire regions like Europe, these differences between countries should be accounted for.

The life cycle of the new system is similar to the baseline system, and figure 10 overall still applies, although a number of processes are altered compared to the baseline system –see color coding in Fig. 12. Note that for reporting conciseness, some of the above explanations as well as Figures 9-11 could be placed in Appendix (not done here).

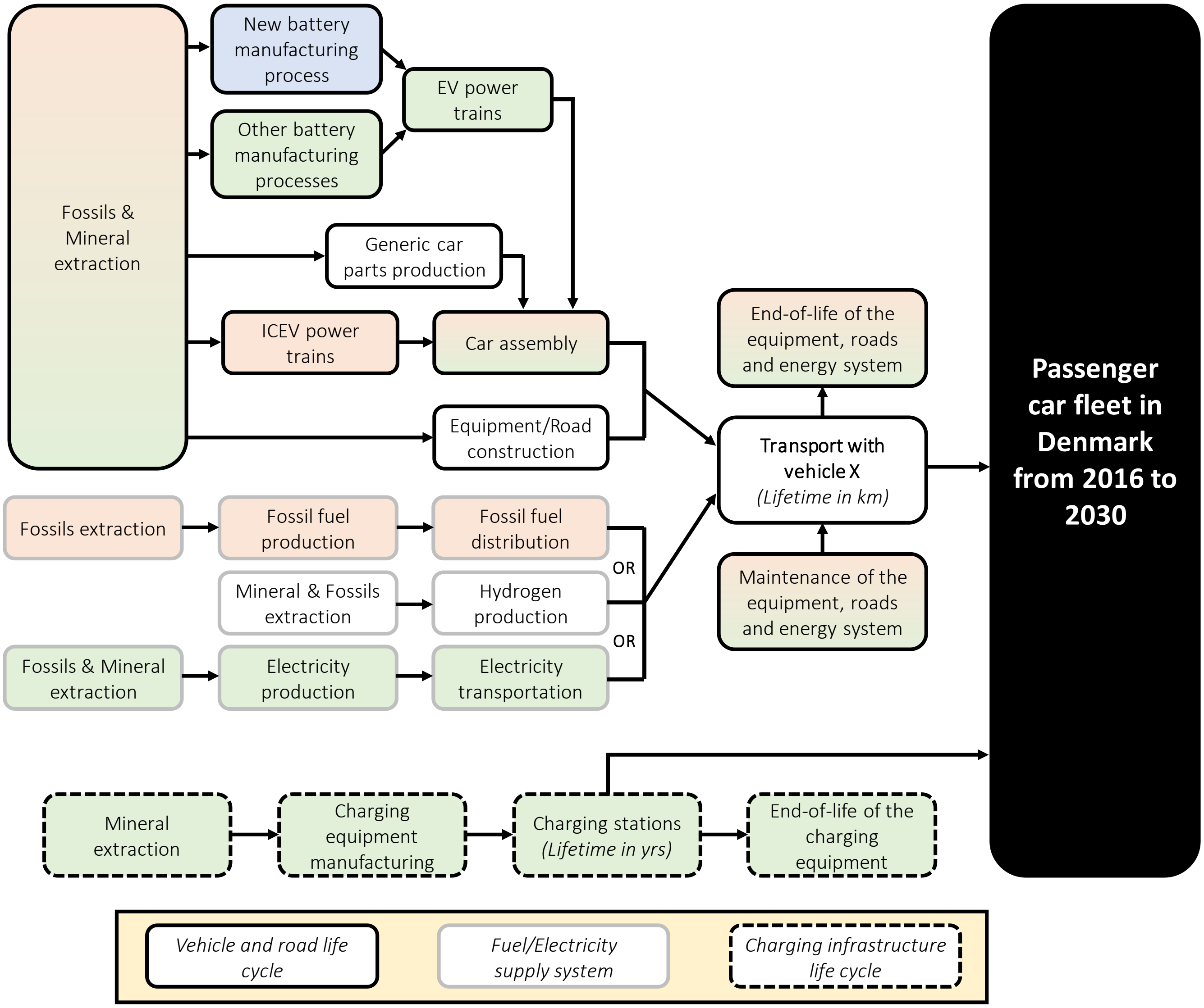


Figure 12. Simplified overview of the life cycle of passenger car fleet in Denmark, as in the new system. Color coding indicates changes compared to baseline (as in Fig. 4 of Methodology); blue: added processes, orange: processes with decreased intensities; green: processes with increased intensities (processes with gradients are affected by both increasing/decreasing intensities depending on specific embedded activities). Based on Bohnes et al. (2017).[13]

3. Phase 3: Inventory of effects from the applications

Table 12 – in the same format as Table 4 in Methodology – reports all direct and indirect effects of the considered project application (increased deployment of EVs) on the baseline life cycle, identifying processes that shall be added, removed and/or altered. Detailed justifications behind the identifications of the effects are provided in Appendix A.

[13] Bohnes F., Gregg J. S., Laurent A., 2017. Environmental impacts of future urban deployment of electric vehicles: a case study of Copenhagen for 2016-2030. *Environ. Sci. Technol.* 51, 13995–14005.

Table 12. Direct and indirect effects of the new system, including non-physical changes, highlighting added (blue) or removed (grey) processes as well as processes with increased (green) and decreased (orange) intensities, compared to the baseline system.

Raw materials	Production	Use	Recycling & End-of-life
		Physical changes	
- Effect 1: increased extraction of rare earth elements needed for production of electric drive motors of EVs - Effect 2: increased extraction of coal, natural gas crude oil or biomass to produce electricity for mining operations of rare earth elements	- Effect 3: increased production of capital goods and equipment to support increased electricity demand from passenger car transport - Effect 4: increased production and installation of charging stations (incl. at households) - Effect 5: decreased production of ICE engines and their supporting equipment (turbines, intercoolers, etc.) - Effect 6: added process of new electrolyte production - Effect 7: increased production of batteries and supporting systems within the cars	- Effect 8: decreased extraction of crude oil for production of diesel and gasoline fuels - Effect 9: decreased food and non-food biomass needed for production of biodiesel and bioethanol fuels - Effect 10: decreased production of diesel, biodiesel, gasoline and bioethanol fuels due to replacing ICE cars with EVs - Effect 11: Increased extraction of coal, natural gas, crude oil and biomass to generate electricity matching increased demand for charging EVs - Effect 12: decreased refueling needs and fuel combustion in the car engine as less fuels is needed for ICEs - Effect 13: increased fuel combustion in fossils-fueled power plants as electricity is needed for charging EVs - Effect 14: increased use of electricity made from renewable sources (wind, solar) for charging EVs	- Effect 16: Increased treatment and landfilling of slags from power plants as more slags will be generated during production of electricity from coal - Effect 17: increased waste management of EV batteries - Effect 18: decreased waste management of ICE engines
		Non-physical changes	
		- Effect 15: Increased driving (km per person) due to extended range capacity of EVs, driving EVs becoming cheaper in use, being perceived as environmentally friendly (e.g. "zero -emissions") by users	

4. PHASE 4: Evaluating the contributions of the application to SDGs

Table B1 in Appendix B reports the links between the effects and the SDGs and their associated targets, together with justifications. Examples of background reasoning for Step 1 of Phase 4 are also reported for pedagogical purposes in Appendix A2.

Table B2 in Appendix B documents the estimations of likelihood and magnitude of the potential impacts of the identified effects on the SDGs, along with their justifications and the quantification of the resulting evaluation score. A brief reasoning example is also provided in Appendix A3 for pedagogical purposes.

The SDG evaluation scores obtained in Table B2 (using the Excel-based tool) is translated graphically into Figure 13.

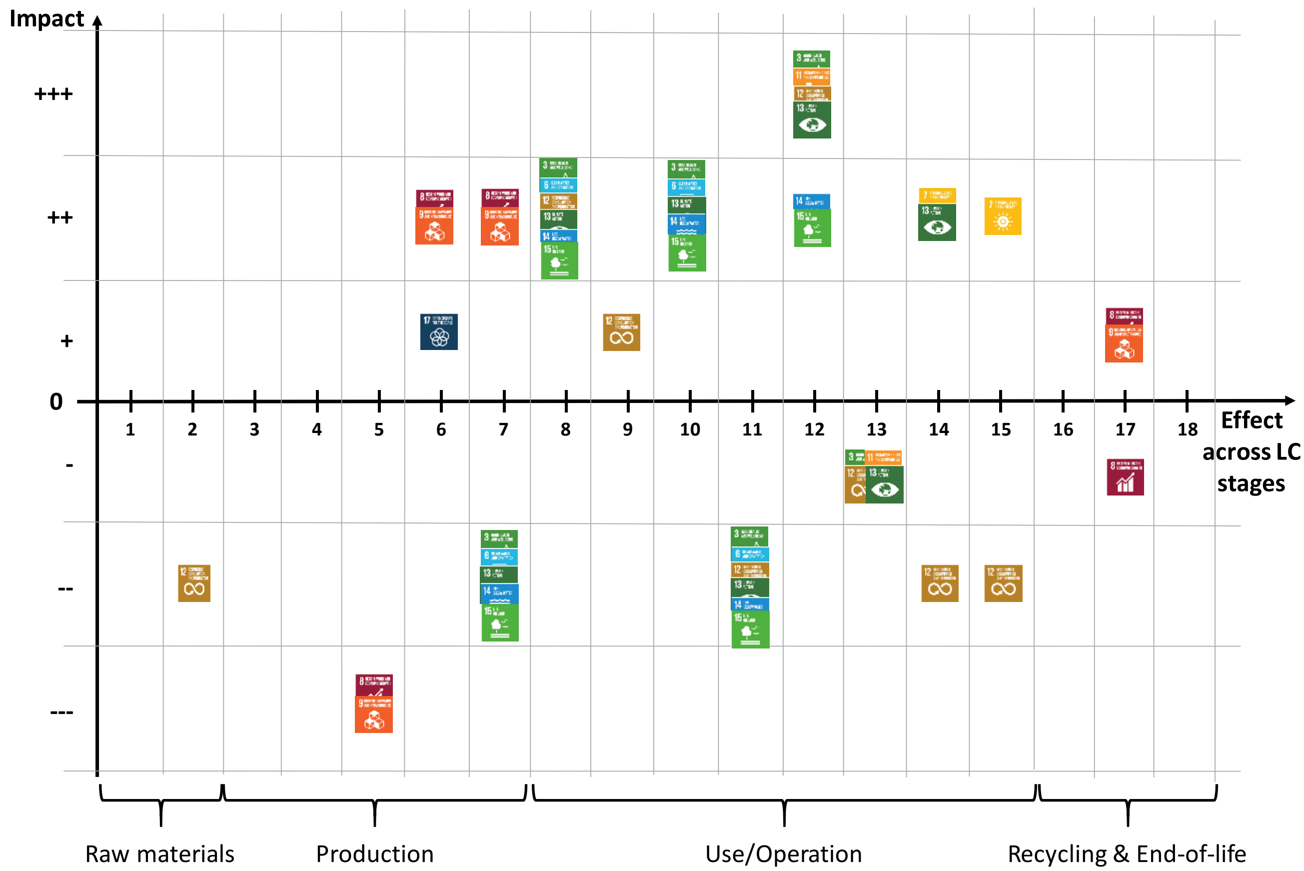


Figure 13. Visual representation of SDG impact assessment for the project of new battery technology development. To make the figure legible, impacts evaluated with negligible contributions are not displayed (hence no SDGs flags for some effects); background scoring of all SDGs and targets is documented for each effect in Appendix B2.

5. INTERPRETATION

Results of the evaluation support the following major observations: (i) slightly more SDGs are impacted positively than negatively, (ii) the number of SDG impacts resulting from cross-SDG links is relatively large (Appendix B1), (iii) the SDG impacts span the entire range of likelihood (from unlikely to likely) and magnitude (from negligible to large, with relatively large representation of negligible and small severity scores), (iv) most of the affected SDGs experience both positive and negative impacts. Relatively large representation of small and negligible severity scores explains why ca. 50% of all impacts are seen as not contributing substantially (that is, impact assimilated/scored as negligible) to their linked targets. These non-contributing impacts are listed in Appendix B2, but are not shown in Figure 13 to make it more legible (and to focus on those effects which matter the most).

Screening results presented in Table B2 and Figure 13 may suggest that the overall contribution of the project to SDG is neither positive nor negative. There are numerous tradeoffs between SDG impacts, and conclusions regarding the overall sustainability contribution of the project depends on the relative importance of the SDGs and their targets, which is not considered in this evaluation.

Tradeoffs between the different life cycle stages are also apparent, and sometimes positive SDG impacts occurring in one stage are countered by negative SDG impacts in another, or even in the same life cycle stage. The project is expected to have positive SDG impact on SDGs 8 and 9 (in the production stage), 3, 6, 7, 11, 12, 14 and 15 (in the use stage) and 8 and 9 (in the end-of life stage). These positive impacts are caused by less demand in fossils-based fuels during car operations, leading to reduction of emissions from car exhaust pipes and reduced extraction of crude oil for production of petroleum fuels; the entire petroleum fuel supply chain is affected. On the other hand, the project is expected to have negative impact on SDGs 12 (raw materials) or 8 and 9, but also 3, 6, 13, 14, 15 (production stage). These impacts are mainly caused by e.g. increased need for battery production efforts and associated impacts (metals resource use and possible emissions). The results also show tradeoffs between effects for specific SDGs. This is most apparent for the environmental SDGs related to human health (SDG 3), climate (SDG 13), life below water (SDG 14) and life on land (SDG 15).

It is seen that negative contribution to some SDGs is caused by the need for production of electricity for charging the EV batteries, which can therefore be considered as a hotspot. Note that the magnitude of this contribution will naturally depend on the nature of the electricity grid mix in the considered geographic location, and which energy sources will become relevant in the future. In the application context of Denmark, this is deemed of less importance as the electricity grid mix is increasingly composed of renewables. When studying potential upscaling of the effects of the project applications (not done here), these should however be considered. The changes in the electricity grid mix are outside the sphere of influence of battery technology developers and the inventor of the new electrolyte. However, the battery developers could focus on optimizing charging conditions to minimize energy losses during charging (particularly when electricity comes from fossils-based sources).

Appendices to the illustrative case study on the project of new battery technology development

Appendix A

- A1. Detailed justifications for effect identification (Phase 3)
- A2. Example of background reasoning for linking effects and SDGs (Phase 4, Step 1)
- A3. Example of background reasoning for SDG impact evaluation (Phase 4, Step 2)

Appendix B

- Table B1. Documentation of linkage between identified effects and SDGs-targets (Step 1 of Phase 4)

  Contains justification of SDG impact and the cross-SDG links (Table 6 as template)

- Table B2. Documentation of evaluation of SDGs-targets impacts (Step 2 of Phase 4)

  Contains detailed SDG impact evaluation, incl. evaluation scores and justifications of likelihoods and magnitudes of the SDG impacts (Table 11 as template)

Note that to keep all information of this guide within a single document, the tables from Appendix B are transferred herein. For actual case studies, these tables should be kept documented within the Excel-based tool and provided as such as an electronic appendix.

Appendix A1 - Detailed justifications for effect identification (Phase 3)

As identified in Phase 2, the main consequence of the new system is to substitute the use of ICE vehicles with EVs (see Figures 9 and 11). Direct effects in the life cycle stages of the new system ensue from this substitution: (i) increase in production of car components specific to EVs (e.g. battery technology, electric drive motors requiring significantly larger amounts of rare earth elements like neodymium and dysprosium, etc.), (ii) decrease in production of car components specific to the ICE vehicles (note that some of this technology is still valid for hybrid vehicles and some of the range-extended EVs), (iii) additional infrastructures to build (e.g. charging stations), (iv) increased electricity demand (and hence of entire value chain of electricity generation in Denmark, which may be supplied by fossil-fuel sources and renewable energy sources like wind power, and may require additional capacity installation), (v) decreased need for gasoline and diesel (hence of entire value chain of petroleum and/or biomass fuels, e.g. decreased need for biodiesel and bioethanol, currently blended in small quantities (<10%) into petroleum fuels), and (vi) increased management of hazardous waste (batteries) and decreased management of conventional engines. Some of those direct effects could also be regarded as indirect when they are consequences that the new battery EV deployment has on other sectors than the transportation sector. As indicated in the methodology, the distinction between direct and indirect effects is not important as long as all effects are identified.

Indirect effects can also be identified as unintended changes caused by introducing EVs. An example is the higher energy requirements for EVs than for ICE vehicles (to heat the inside of the car in cold weather in Denmark: with ICE vehicles this heating comes from waste heat from the engine). That increases the energy demand needed to support EV transport above the requirements for propelling the car. This may put additional pressure on the electricity grid, which in turn may have implications for the electricity supply for transportation and other sectors (safety or stability, e.g. shortage, disruption, etc.). Another example of an indirect effect could be that several EVs drivers will install a charging station at home, which may require to adapt or change the electric installation of their houses.

In addition to these physical changes, non-physical changes are also relevant to consider. The new battery EVs and their extended range may influence user behavior in several ways. The increased attractiveness of EVs with extended range capacity (and lower operation costs that compensate the higher investment costs, compared to ICE vehicles) may lead to more driving, and this should be reflected in the projections defining the new system; this is what explains most of the differences between the baseline and the new system. Other behavioral changes, which could potentially be influential, are that customers may drive more (e.g. to seek charging stations with lowest costs or better service, because it is cheaper than driving with ICE vehicles) or differently (more or less acceleration/deceleration resulting in different energy needs, more comfortable driving). Government incentives or regulations could also influence such behavior changes in the population. In the specific case study of EVs, market studies could include evolutions of transportation patterns under different conditions or scenarios. This information could then support the definition of projections for the new system. Such projections can be fine-tuned iteratively between Phases 2 and 3 based on the identification of the effects to arrive at the projections displayed in Figure 11.

Finally, other non-physical effects could be considered, including the new business opportunities generated by the development of the new battery technology, like economic growth in the electronics sector or EV sector, and the likely recession of the sectors dependent on the ICE technology.

A number of processes identified in Table 12 can be classified as likely not to change, albeit there can be some uncertainty about the actual effect. These processes include: i) extraction of metal ores Cu, Al, Fe, with some uncertainty about material needs of additional infrastructures for charging; ii) manufacturing of different power trains, with some uncertainty about manufacturing of electric drive motors; iii) manufacturing of common car parts, as many parts of ICE and EVs are similar and are provided by the same suppliers; iv) assembly of a car, as assembly of both ICE car and an EV are expected to be similar; v) maintenance of an EV car, although there is uncertainty about functional long-term performance of new battery which may require replacement; vi) dismantling of system/capital goods and cars, with effect to uncertain to include as dismantling of charging station is not currently done; vii) reuse of some car parts, where no change is expected as many car components, be it an ICE car or EV, are the same and can be reused; viii) shredding, where no change is expected because EVs are currently disposed of in the same way as ICE cars are; ix) recycling of metals, where again no change is expected; and x) landfilling of post-shredding residue, where again no change is expected.

Appendix A2 – Example of background reasoning for linking effects and SDGs

To fill in Table B1, all SDGs and underlying targets were screened to identify potential links with the effect. For each of the effects, a causality chain can be visualized to identify the potential SDGs and underlying targets. Figure A2-1 shows an example for the effect "*decreased fuel combustion in car engines as less fuel is needed by the ICEs*".

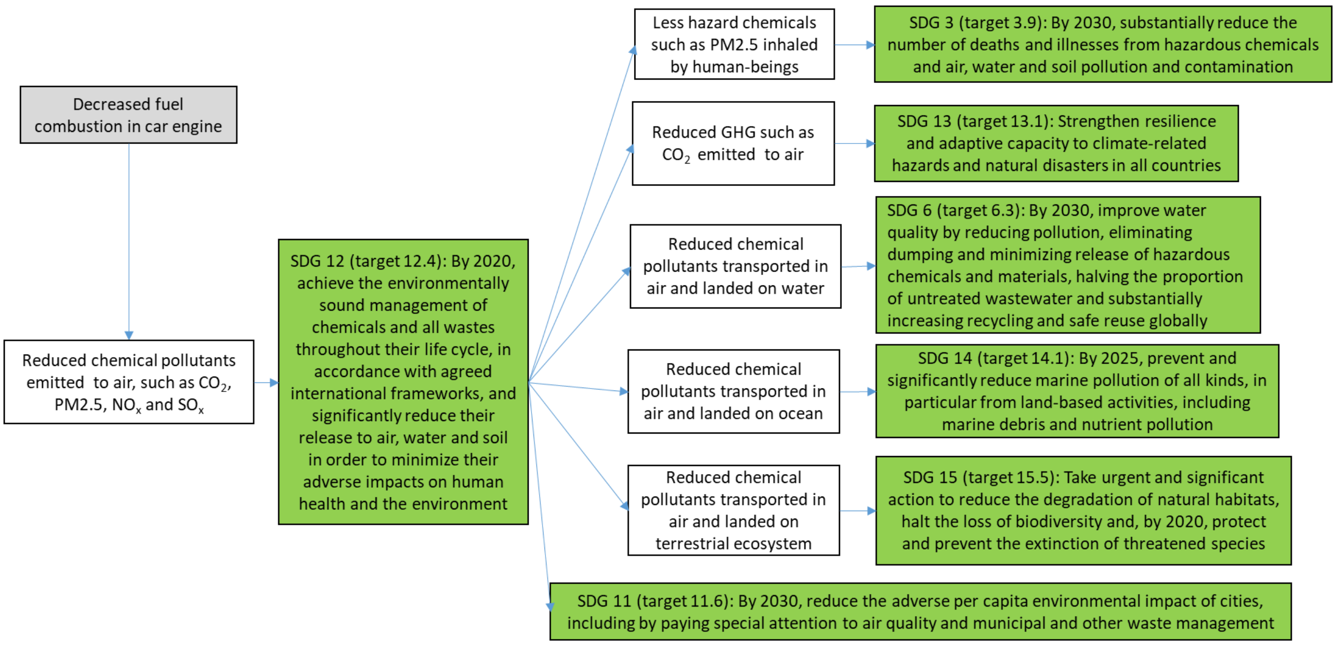


Figure A2-1. Causality chain of the effect "decreased fuel combustion in ICE car engines".

To inspire the establishment of connections across SDGs, the cross-SDG links between SDG targets were identified with support of an online tool https://sdginterlinkages.iges.jp/visualisationtool.html. For example, when target no. 4 of SDG 12 on "responsible production and consumption" is identified as relevant for the above effect, this target is selected in the online tool, and many potentially linked targets appears, as shown in Figure A2-2. To proceed, it is important to carefully read each of the SDG targets that are interlinked with SDG target 12.4, and identify the ones that are relevant for the considered effect.

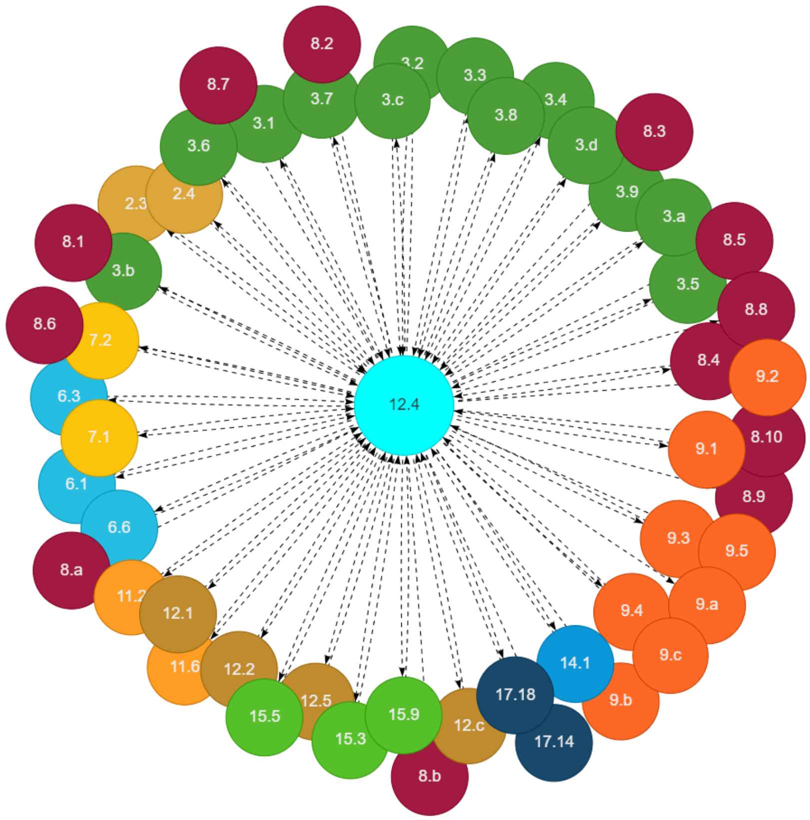


Figure A2-2. Interlinkages between SDG target 12.4 and other SDG targets (marked as X.Y for Goal X and respective target Y), retrieved from https://sdginterlinkages.iges.jp/visualisationtool.html

Appendix A3 – Example of background reasoning for SDG impact evaluation

The judgement of likelihood, it is an expert judgement, which should be based on science-based evidence as much as possible. For example, the decreased fuel combustion in the car engine will very likely reduce the chemicals releases to the environment (SDG 12, target 12.4), as the direct impacts arising from this effect. Chemicals may further transport to and affect terrestrial ecosystems (SDG 15). It is an indirect impact from target 12. The likelihood depends on how far the pollutants may transport and how much may land on terrestrial ecosystem thus causing biodiversity loss there. Thus the impact of this effect on SDG 15 is possible.

The judgement of magnitude should use the potential maximum achievement of a specific SDG target as reference. For example, target 11.6 is to reduce the adverse per capital environmental impacts of cities. As the air pollution from transport is one of the major contributors to this target, the achievement of reducing fuel combustion may be considered as major in magnitude.

Appendix B1 – Documentation of linkage between identified effects and SDGs-targets (Step 1 of Phase 4)

Table B1. Identification and justifications of SDG-target impacts caused by the effects listed in Table 12 (extracted from Excel-based tool).

Effect	SDG	Target	Justification for SDG-Targets impacts	Justification for interlinked SDG-Targets impacts
Effect 1: Increased extraction of rare earth elements needed for production of electric drive motors of EVs	SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Increased extraction of rare earth elements will result in release of chemicals (e.g. from mine tailings) into environment around the mining area	The main interlinkage of target 3.9 is with SDG 6 (clean water and sanitation), SDG13, SDG 14 (life below water) and SDG 15 (life on land) because chemical pollutants causing impacts on human health, like metals in mine tailings, are also known to be ecotoxic to organisms
	SDG 12. Ensure sustainable consumption and production patterns	12.2 By 2030, achieve the sustainable management and efficient use of natural resources	Increased extraction of rare earth elements will contribute negatively to this target through the use of natural resources	The main interlinkages of target 12.2 are with SDG 6 (clean water), 14 (life below water) and 15 (life on land) because extraction of rare earth elements is also causing environmental pollution with potential ecotoxic effects on organisms
	SDG 13. Take urgent action to combat climate change and its impacts	13.1. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Caused by the impacted target 12.2	Increased extraction of rare earth elements may cause GHG emissions from mining and refining operations, mainly CO2, thus contributing to climate change
	SDG 6. Ensure availability and sustainable management of water and sanitation for all	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Caused by the impacted target 3.9 and 12.2	Increased extraction of rare earth elements may results in release of chemicals from mining waste (e.g. metals), thereby contaminating freshwater bodies
	SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Caused by the impacted target 3.9 and 12.2	Increased extraction of rare earth elements may results in release of chemicals from mining waste (e.g. metals), thereby polluting coastal and marine waters
	SDG 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Caused by the impacted target 3.9 and 12.2	Increased extraction of rare earth elements may results in transformation of land inhabited by terrestrial species into new mining areas, and in release of chemicals from mining waste (e.g. metals) to soils, thereby contributing to loss of biodiversity

Effect 2: Increased extraction of coal, natural gas crude oil or biomass to produce electricity for mining operations of rare earth elements	SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Increased extraction of fossil fuels may result in release of chemicals (e.g. hydrocarbons from oil wells) into environment around the extraction area	The main interlinkage of target 3.9 is with SDG 6 (clean water and sanitation), SDG 13 (climate action) SDG 14 (life below water) and SDG 15 (life on land) because chemical pollutants causing impacts on human health, like hydrocarbons, are also known to be ecotoxic to organisms
	SDG 12. Ensure sustainable consumption and production patterns	12.2 By 2030, achieve the sustainable management and efficient use of natural resources	Increased extraction of fossil fuels will contribute negatively to this target through the use of natural resources	The main interlinkages of target 12.2 are with SDG 6 (clean water), 14 (life below water) and 15 (life on land) because extraction of fossil fuels is also causing environmental pollution with ecotoxic effects on organisms living in terrestrial, freshwater and marine environments; and because extraction of fossil fuels causes GHG emissions
	SDG 13. Take urgent action to combat climate change and its impacts	13.1. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Caused by the impacted target 12.2	Increased extraction of fossil fuels or biomass may cause GHG emissions from extraction operations, mainly CO2 and CH4, thus contributing to climate change
	SDG 6. Ensure availability and sustainable management of water and sanitation for all	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Caused by the impacted target 3.9 and 12.2	Increased extraction of fossil fuels may results in release of chemicals during extraction, thereby contaminating freshwater bodies
	SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Caused by the impacted target 3.9 and 12.2	Increased extraction of fossil fuels may results in release of chemicals during extraction, thereby polluting coastal and marine waters
	SDG 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Caused by the impacted target 3.9 and 12.2	Increased extraction of fossil fuels may results in transformation of land inhabited by terrestrial species into extraction sites, and in release of chemicals from mining waste to soils, thereby contributing to loss of biodiversity

Effect 3: Increased production of capital goods and equipment to support increased electricity demand from passenger car transport	SDG 12. Ensure sustainable consumption and production patterns	12.2 By 2030, achieve the sustainable management and efficient use of natural resources	Increased extraction of metals for production of capital goods and equipment will contribute negatively to this target through the use of natural resources	The main interlinkages of target 12.2 are with SDG 6 (clean water), 13 (climate action), 14 (life below water) and 15 (life on land) because extraction of metals is also causing environmental pollution with potential ecotoxic effects on organisms and because production of infrastructures and refining of metals (e.g. metallurgy) is associated with CO2 emissions
	SDG 13. Take urgent action to combat climate change and its impacts	13.1. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Caused by the impacted target 12.2	Increased production of capital goods and equipment, containing metals, may cause GHG emissions, mainly CO2, thereby contributing to climate change
	SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Caused by the impacted target 12.2	Increased production of capital goods and equipment may results in release of potentially toxic chemicals from manufacturing processes, thereby impacting human health
	SDG 6. Ensure availability and sustainable management of water and sanitation for all	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Caused by the impacted target 12.2	Increased production of capital goods and equipment may results in release of potentially toxic chemicals from manufacturing processes into environment, thereby impacting water quality
	SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Caused by the impacted target 12.2	Increased production of capital goods and equipment may results in release of potentially toxic chemicals from manufacturing processes into environment, thereby polluting coastal and marine waters
	SDG 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Caused by the impacted target 12.2	Increased production of capital goods and equipment may results in release of chemicals from manufacturing processes into environment, thereby contributing to loss of biodiversity

Effect 4: Increased production and installation of charging stations (incl. at households)	SDG 12. Ensure sustainable consumption and production patterns	12.2 By 2030, achieve the sustainable management and efficient use of natural resources	Increased extraction of metals for production of charging stations will contribute negatively to this target through the use of natural resources	The main interlinkages of target 12.2 are with SDG 6 (clean water), 14 (life below water) and 15 (life on land) because extraction of metals is also causing environmental pollution with potential ecotoxic effects on organisms and because refining of metals (e.g. metallurgy) and manufacturing processes are associated with CO2 emissions
	SDG 13. Take urgent action to combat climate change and its impacts	13.1. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Caused by the impacted target 12.2	Increased production of charging stations, containing metals, may cause GHG emissions, mainly CO2, thereby contributing to climate change
	SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Caused by the impacted target 12.2	Increased production of charging stations may results in release of potentially toxic chemicals from manufacturing processes, thereby impacting human health
	SDG 6. Ensure availability and sustainable management of water and sanitation for all	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Caused by the impacted target 12.2	Increased production of charging stations may results in release of potentially toxic chemicals from manufacturing processes into environment, thereby impacting water quality
	SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Caused by the impacted target 12.2	Increased production of charging stations may results in release of potentially toxic chemicals from manufacturing processes into environment, thereby polluting coastal and marine waters
	SDG 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Caused by the impacted target 12.2	Increased production of charging stations may results in release of chemicals from manufacturing processes into environment, contributing to loss of biodiversity
Effect 5: Decreased production of ICE engines and their supporting equipment (turbines, intercoolers, etc.)	SDG 12. Ensure sustainable consumption and production patterns	12.2 By 2030, achieve the sustainable management and efficient use of natural resources	Decreased extraction of metals for production of ICE engines will contribute positively to this target through reducing the use of natural resources	The main interlinkages of target 12.2 are with SDG 6 (clean water), 14 (life below water) and 15 (life on land) because extraction of metals is also causing environmental pollution with potential ecotoxic effects on organisms and because refining of metals (e.g. metallurgy) and metal parts manufacturing processes are associated with CO2 emissions

	SDG 13. Take urgent action to combat climate change and its impacts	13.1. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Caused by the impacted target 12.2	Decreased production of ICE engines and their supporting equipment may decrease GHG emissions, mainly CO2, thereby contributing to climate change mitigation
	SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9. By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Caused by the impacted target 12.2	Decreased production of ICE engines and their supporting equipment may decrease release of potentially toxic chemicals from manufacturing processes, thereby reducing impact on human health
	SDG 6. Ensure availability and sustainable management of water and sanitation for all	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Caused by the impacted target 12.2	Decreased production of ICE engines and their supporting equipment may decrease release of potentially toxic chemicals from manufacturing processes into environment, thereby reducing impact on water quality
	SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Caused by the impacted target 12.2	Decreased production of ICE engines and their supporting equipment may decrease release of potentially toxic chemicals from manufacturing processes into environment, thereby reducing pollution of coastal and marine waters
	SDG 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Caused by the impacted target 12.2	Decreased production of of ICE engines and their supporting equipment may decrease release of chemicals from manufacturing processess into environment, thereby contributing to halting loss of biodiversity
	SDG 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries	Decrease in revenues in sectors linked to ICE technology may have negative impact on economic growth as economic performance of ICE engine manufacturers can be challenged	The main interlinkage of target 8.1 is with SDG 9 (Industry, innovation and infrastructure)
	SDG 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries	Caused by the impacted target 8.1	Decrease in revenues in sectors linked to ICE technologies is expected to decrease industry's share of employment and GDP

Effect 6: Added process of new electrolyte production	SDG 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries	Increase in revenues in sectors linked to EVs is expected to contribute to economic growth	The main interlinkage of target 8.1 is with SDG 9 (Industry, innovation and infrastructure)
	SDG 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries	Caused by the impacted target 8.1	Increase in revenues in sectors linked to EVs is expected to raise industry's share of employment and GDP
	SDG 17. Strengthen the means of implementation and revitalize the global partnership for sustainable development	17.16 Enhance the global partnership for sustainable development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the sustainable development goals in all countries, in particular developing countries	Creation of new partnerships between different actors within the electronics sector (with usage of batteries), incl. partnerships with authorities and public institutions	-
Effect 7: Increased production of batteries and supporting systems within the cars	SDG 12. Ensure sustainable consumption and production patterns	12.2 By 2030, achieve the sustainable management and efficient use of natural resources	Increased extraction of metals for production of batteries and EV engines will contribute negatively to this target through increasing use of natural resources (at least until efficient market for recycling of batteries is in place)	The main interlinkages of target 12.2 are with SDG 6 (clean water), 14 (life below water) and 15 (life on land) because extraction of metals is also causing environmental pollution with potential ecotoxic effects on organisms and because refining of metals (e.g. metallurgy) and metal parts manufacturing processes are associated with CO2 emissions
	SDG 13. Take urgent action to combat climate change and its impacts	13.1. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Caused by the impacted target 12.2	Increased production of batteries, EV engines and their supporting equipment may increase GHG emissions, mainly CO2, thereby contributing to climate change
	SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9. By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Caused by the impacted target 12.2	Increased production of batteries, EV engines and their supporting equipment may increase release of potentially toxic chemicals from manufacturing processes, thereby increasing impact on human health
	SDG 6. Ensure availability and sustainable management of water and sanitation for all	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Caused by the impacted target 12.2	Increased production of batteries, EV engines and their supporting equipment may increase release of potentially toxic chemicals from manufacturing processes into environment, thereby increasing impact on water quality

	SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Caused by the impacted target 12.2	Increased production of batteries, EV engines and their supporting equipment may increase release of potentially toxic chemicals from manufacturing processes into environment, thereby increasing pollution of coastal and marine waters
	SDG 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Caused by the impacted target 12.2	Increased production of batteries, EV engines and their supporting equipment may increase release of chemicals from manufacturing processes into environment, thereby contributing to loss of biodiversity
	SDG 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries	Increase in revenues in sectors linked to EVs is expected to contribute to economic growth	The main interlinkage of target 8.1 is with SDG 8 (Decent work and economic growth) SDG 9 (Industry, innovation and infrastructure)
	SDG 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead	Caused by the impacted target 8.1	Increase in revenues in sectors linked to EVs, in particular electronics and rare earth elements supply, is expected to decrease global resource efficiency as more metals will be mined
	SDG 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries	Caused by the impacted target 8.1	Increase in revenues in sectors linked to EVs is expected to raise industry's share of employment and GDP
Effect 8: Decreased extraction of crude oil for production of diesel and gasoline fuels	SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Decreased extraction of fossil fuels may reduce release of chemicals (e.g. hydrocarbons from oil wells) into environment around the extraction area	The main interlinkage of target 3.9 is with SDG 6 (clean water and sanitation), SDG 13 (climate action) SDG 14 (life below water) and SDG 15 (life on land) because chemical pollutants causing impacts on human health, like hydrocarbons, are also known to be ecotoxic to organisms, and because extraction of fossil fuels causes GHG emissions

	SDG 12. Ensure sustainable consumption and production patterns	12.2 By 2030, achieve the sustainable management and efficient use of natural resources	Decreased extraction of fossil fuels will contribute positively to this target through reducing the use of natural resources	The main interlinkages of target 12.2 are with SDG 6 (clean water), 14 (life below water) and 15 (life on land) because extraction of fossil fuels is also causing environmental pollution with ecotoxic effects on organisms
	SDG 13. Take urgent action to combat climate change and its impacts	13.1. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Caused by the impacted target 12.2	Decreased extraction of crude oil will reduce GHG emissions from extraction operations, mainly CO2 and CH4, thus contributing to climate change
	SDG 6. Ensure availability and sustainable management of water and sanitation for all	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Caused by the impacted target 3.9 and 12.2	Decreased extraction of crude oil may reduce release of chemicals during extraction, thereby contributing to maintaining freshwater quality
	SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Caused by the impacted target 3.9 and 12.2	Decreased extraction of crude oil may reduce release of chemicals during extraction, thereby contributing to maintaining coastal and marine water quality
	SDG 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Caused by the impacted target 3.9 and 12.2	Decreased extraction of fossil fuels may prevent transformation of land inhabited by terrestrial species into extraction sites, and reduce release of chemicals from mining waste thereby contaminating soils, both contributing to halting loss of biodiversity
Effect 9: Decreased extraction of food and non-food biomass needed for production of biodiesel and bioethanol fuels	SDG 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture	2.1. By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round	Decrease use of food biomass for biofuel production may increase the availability of biomass used as source of food	The main interlinked of target 2.1 is with SDG 1 (no poverty)
	SDG 12. Ensure sustainable consumption and production patterns	12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	Decreased use of non-food biomass for biodiesel production can increase amount of (bio)waste for treatment	The main interlinkage of target 12.5 is with SDG 6 (clean water)
	SDG 1. End poverty in all its forms everywhere	1.2 By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions	Caused by the impacted target 2.1	Increasing availability of food is expected to reduce poverty in general

	SDG 6. Ensure availability and sustainable management of water and sanitation for all	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Caused by the impacted target 12.5	Decreased reuse of carbon in non-food biomass may decrease release of chemicals from (bio)waste into water
Effect 10: Decreased production of diesel, biodiesel, gasoline and bioethanol fuels due to replacing ICE cars with EVs	SDG 12. Ensure sustainable consumption and production patterns	12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment	Decreased production of fossil fuels may reduce release of chemicals (e.g. hydrocarbons from oil wells) into environment around the extraction area	The main interlinkages of target 12.4 are with SDG 3 (good health and well-being), SDG 6 (clean water and sanitation), SDG 14 (life below water) and SDG 15 (life on land).
	SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Caused by the impacted target 12.4	Decrease production of fuels will reduce emission of hazardous chemicals to air, water and soil, thus reducing number of deaths and illnesses from chemicals
	SDG 6. Ensure availability and sustainable management of water and sanitation for all	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Caused by the impacted target 12.4	Decrease production of fuels will reduce emissions of water contaminants from production processes
	SDG 13. Take urgent action to combat climate change and its impacts	13.1. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Caused by the impacted target 12.4	Decreased production of fuels is expected to decrease GHG emissions, mainly CO2 and nitrogen oxides, thus contributing to climate change mitigation
	SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1. By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Caused by the impacted target 12.4	Decreased production of fuels may reduce release of chemicals during production, thereby reducing pollution of coastal and marine waters
	SDG 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Caused by the impacted target 12.4	Decreased production of fuels may reduce release of chemicals from production processess, contributing to halting biodiversity loss

Effect 11: Increased extraction of coal, natural gas, crude oil and biomass to generate electricity for charging EVs	SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Increased extraction of fossil fuels may result in release of chemicals (e.g. hydrocarbons from oil wells) into environment around the extraction area	The main interlinkage of target 3.9 is with SDG 6 (clean water and sanitation), SDG 13 (climate action) SDG 14 (life below water) and SDG 15 (life on land) because chemical pollutants causing impacts on human health, like hydrocarbons, are also known to be ecotoxic to organisms, and because extraction of fossil fuels causes GHG emissions
	SDG 12. Ensure sustainable consumption and production patterns	12.2 By 2030, achieve the sustainable management and efficient use of natural resources	Increased extraction of fossil fuels will contribute negatively to this target through the use of natural resources	The main interlinkages of target 12.2 are with SDG 6 (clean water), 14 (life below water) and 15 (life on land) because extraction of fossil fuels is also causing environmental pollution with ecotoxic effects on organisms living in terrestrial, freshwater and marine environments
	SDG 13. Take urgent action to combat climate change and its impacts	13.1. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Caused by the impacted target 12.2	Increased extraction of fossil fuels or biomass may cause GHG emissions from extraction operations, mainly CO_2 and CH_4, thus contributing to climate change
	SDG 6. Ensure availability and sustainable management of water and sanitation for all	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Caused by the impacted target 3.9 and 12.2	Increased extraction of fossil fuels may results in release of chemicals during extraction, thereby contaminating freshwater bodies
	SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Caused by the impacted target 3.9 and 12.2	Increased extraction of fossil fuels may results in release of chemicals during extraction, thereby polluting coastal and marine waters
	SDG 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Caused by the impacted target 3.9 and 12.2	Increased extraction of fossil fuels may results in transformation of land inhabited by terrestrial species into extraction sites, and in release of chemicals to soils, thereby contributing to loss of biodiversity

Effect 12: Decreased fuel combustion in the car engine as less fuels is needed for ICEs	SDG 12. Ensure sustainable consumption and production patterns	12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment	Decrease of fuel combustion will reduce emissions of CO2, chemicals (e.g. nitrogen oxides) and particulate matter to the air	The main interlinkages of target 12.4 are with SDG 3 (good health and well-being), SDG 11 (sustainable cities and communities), SDG 13 (climate action) and 15 (life on land)
	SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Caused by the impacted target 12.4	Decreased fuel combustions and resulting reduction in emissions of nitrogen oxides and particulate matter are expected to reduce number of deaths and illnesses
	SDG 11. Make cities and human settlements inclusive, safe, resilient and sustainable	11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	Caused by the impacted target 12.4	Decreased fuel combustion and resulting reduction in emissions of particulate matter is expected to reduce environmental impact of cities on transport sector, improving the air quality
	SDG 13. Take urgent action to combat climate change and its impacts	13.1. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Caused by the impacted target 12.4	Decreased fuel combustion and resulting reduction in CO2 emissions is expected to reduce climate change impact
	SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Caused by the impacted target 3.9 and 12.2	Decreased fuel combustion and associated emissions of pollutants may result in less pollution on coastal and marine waters (via nitrogen oxides, metals)
Effect 13: Increased fuel combustion in power stations as electricity is needed for charging EVs	SDG 12. Ensure sustainable consumption and production patterns	12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment	Increase of fuel combustion will increase emissions of CO2, nitrogen oxides and particulate matter to the air	The main interlinkages of target 12.4 are with SDG 3 (good health and well-being), SDG 11 (sustainable cities and communities), SDG 13 (climate action) and 15 (life on land).
	SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Caused by the impacted target 12.4	Increased fuel combustion and resulting increase in emissions of nitrogen oxides and particulate matter are expected to reduce number of deaths and illnesses
	SDG 11. Make cities and human settlements inclusive, safe, resilient and sustainable	11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to	Caused by the impacted target 12.4	Increased fuel combustion and resulting increase in emissions of particulate matter is expected to decrease air quality

		air quality and municipal and other waste management		
	SDG 13. Take urgent action to combat climate change and its impacts	13.1. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Caused by the impacted target 12.4	Increased fuel combustion and resulting increase in CO2 emissions is expected to increase climate change impact
	SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Caused by the impacted target 3.9 and 12.2	Increased fuel combustion and associated emissions of pollutants may result in more pollution on coastal and marine waters (via nitrogen oxides, metals)
Effect 14: Increased use of electricity made from renewable sources (wind, solar) for charging EVs	SDG 7. Ensure access to affordable, reliable, sustainable and modern energy for all	7.2 By 2030, increase substantially the share of renewable energy in the global energy mix	Increased power generation from renewable sources may increase the share of renewable energy in the global mix	The main interlinkage of target 7.2 is with SDG 13 (climate action)
	SDG 12. Ensure sustainable consumption and production patterns	12.2 By 2030, achieve the sustainable management and efficient use of natural resources	Increased used of metals, including rare earth elements, for wind turbines or solar cells is expected to contribute negatively to this target through the use of natural resources	The main interlinkage of target 12.2 is with SDG 6 (clean water and sanitation), SDG 14 (life below water) and 15 (life on land).
	SDG 13. Take urgent action to combat climate change and its impacts	13.1. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Caused by the impacted target 7.2	Use of wind turbines or solar cells to generate electricity is expected to contribute to climate change mitigation
	SDG 6. Ensure availability and sustainable management of water and sanitation for all	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Caused by the impacted target 12.2	Increased use of metals may results in release of chemicals from mining waste, thereby contaminating freshwater bodies
	SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Caused by the impacted target 12.2	Increased use of metals may results in release of chemicals from mining waste, thereby polluting coastal and marine waters

	SDG 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Caused by the impacted target 12.2	Increased use of metals may results in transformation of land inhabited by terrestrial species into new mining areas, and in release of chemicals from mining waste to soils, thereby contributing to loss of biodiversity
Effect 15: Increased driving (km per person) due to extended range capacity of EVs, driving EVs becoming cheaper in use, being perceived as environmentally friendly (e.g. "zero -emissions") by users	SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Increase driving, will lead to decreased extraction of fossil fuels for petroleum production which will result in more chemical pollutants (e.g. hydrocarbons from oil wells) emitted into environment around the extraction area	The main interlinkage of target 3.9 is with SDG 6 (clean water and sanitation), SDG 13 (climate action) SDG 14 (life below water) and SDG 15 (life on land) because chemical pollutants causing impacts on human health, like hydrocarbons, are also known to be ecotoxic to organisms, and because extraction of fossil fuels causes GHG emissions
	SDG 12. Ensure sustainable consumption and production patterns	12.2 By 2030, achieve the sustainable management and efficient use of natural resources	Increase driving, will lead to decreased extraction of fossil fuels for petroleum production, which will contribute negatively to this target through the use of natural resources	The main interlinkages of target 12.2 are with SDG 6 (clean water), 14 (life below water) and 15 (life on land) because extraction of fossil fuels is also causing environmental pollution with ecotoxic effects on organisms living in terrestrial, freshwater and marine environments
	SDG 12. Ensure sustainable consumption and production patterns	12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment	Increase driving will lead to increase of fuel combustion in power stations that will increase emissions of CO2, nitrogen oxides and particulate matter to the air	The main interlinkages of target 12.4 are with SDG 3 (good health and well-being), SDG 11, SDG 13 (climate action) and 15 (life on land).
	SDG 7. Ensure access to affordable, reliable, sustainable and modern energy for all	7.2 By 2030, increase substantially the share of renewable energy in the global energy mix	Increase in driving will lead to increased power generation from renewable sources which may increase the share of renewable energy in the global mix	The main interlinkage of target 7.2 is with SDG 13 (climate action)
	SDG 12. Ensure sustainable consumption and production patterns	12.2 By 2030, achieve the sustainable management and efficient use of natural resources	Increase in driving will lead to an increase in used of metals, including rare earth elements, for wind turbines or solar cells which is expected to contribute negatively to this target through the use of natural resources	The main interlinkage of target 12.2 is with SDG 6 (clean water and sanitation), SDG 14 (life below water) and 15 (life on land).
	SDG 13. Take urgent action to combat climate change and its impacts	13.1. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Caused by the impacted target 12.2	Increased extraction of fossil fuels or biomass may cause GHG emissions from extraction operations, mainly CO2 and CH4, thus contributing to climate change

SDG 6. Ensure availability and sustainable management of water and sanitation for all	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Caused by the impacted target 3.9 and 12.2	Increased extraction of fossil fuels may results in release of chemicals during extraction, thereby contaminating freshwater bodies
SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Caused by the impacted target 3.9 and 12.2	Increased extraction of fossil fuels may results in release of chemicals during extraction, thereby polluting coastal and marine waters
SDG 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Caused by the impacted target 3.9 and 12.2	Increased extraction of fossil fuels may results in transformation of land inhabited by terrestrial species into extraction sites, and in release of chemicals from mining waste thereby contaminating soils, both contributing to loss of biodiversity
SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Caused by the impacted target 12.4	Increased fuel combusions and resulting increase in emissions of nitrogen oxides and particulate matter are expected to increase number of deaths and ilnessess
SDG 11. Make cities and human settlements inclusive, safe, resilient and sustainable	11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	Caused by the impacted target 12.4	Increased fuel combusions and resulting increase in emissions of particulate matter and aerosols is expected to increase environmental impact of cities on transport sector, decreasing the air quality
SDG 13. Take urgent action to combat climate change and its impacts	13. 1. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Caused by the impacted target 12.4	Increased fuel combusions and resulting increase in CO2 emissions is expected to increase climate change impact
SDG 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Caused by the impacted target 12.4	Increased fuel combusions and resulting increase in CO2 emissions from combusion of fuels is expected to increase climate change impact, thereby contributing to biodiversity loss
SDG 13. Take urgent action to combat climate change and its impacts	13. 1. Strengthen resilience and adaptive capacity to climate-related	Caused by the impacted target 7.2	Use of wind turbines or solar cells to generate electricity is expected to strengthen adaptive capacity to climate change

		hazards and natural disasters in all countries		
	SDG 6. Ensure availability and sustainable management of water and sanitation for all	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Caused by the impacted target 12.2	Increased use of metals may results in release of chemicals from mining waste, thereby contaminating freshwater bodies
	SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Caused by the impacted target 12.2	Increased use of metals may results in release of chemicals from mining waste, thereby polluting coastal and marine waters
	SDG 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Caused by the impacted target 12.2	Increased use of metals may results in transformation of land inhabited by terrestrial species into new mining areas, and in release of chemicals from mining waste thereby contaminating soils, both contributing to loss of biodiversity
Effect 16: Increased treatment and landfilling of slags from power plants as more slags will be generated during production of electricity from coal	SDG 11. Make cities and human settlements inclusive, safe, resilient and sustainable	11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	Increasing generation and landfilling of slags is expected to increase environmental impact of cities though increase in waste	The main interlinkage of target 11.6 is with SDG 3 (Good health and well-being) SDG 12 (responsible consumption and production)
	SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Caused by the impacted target 11.6	Increasing generation and landfilling of slags is expected to cause environmental pollution thereby increasing human health impacts

	SDG 12. Ensure sustainable consumption and production patterns	12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment	Caused by the impacted target 11.6	Increasing generation and landfilling of slags is expected to increase release of chemicals from the slags into the environment
	SDG 12. Ensure sustainable consumption and production patterns	12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	Caused by the impacted target 11.6	Increasing generation of slags increases waste generation in general
Effect 17: Increased waste management of EV batteries	SDG 11. Make cities and human settlements inclusive, safe, resilient and sustainable	11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	Increasing generation and treatment of EV batteries is expected to increase environmental impact of cities though increase in waste	The main interlinkage of target 11.6 is with SDG 3 (Good health and well-being) SDG 12 (responsible consumption and production)
	SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Caused by the impacted target 11.6	Increasing treatment of EV batteries is expected to cause environmental pollution thereby increasing human health impacts
	SDG 12. Ensure sustainable consumption and production patterns	12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment	Caused by the impacted target 11.6	Increasing treatment of EV batteries may increase release of chemicals from the batteries into the environment
	SDG 12. Ensure sustainable consumption and production patterns	12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	Caused by the impacted target 11.6	Increasing treatment of EV batteries increases waste generation in general
	SDG 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries	Increase in revenues in sectors linked to EVs is expected to contribute to economic growth	The main interlinkage of target 8.1 is with SDG 8 (Decent work and economic growth) SDG 9 (Industry, innovation and infrastructure)

	SDG 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead	Caused by the impacted target 8.1	Increase in revenues in sectors linked to EVs, in particular electronics and rare earth elements supply, is expected to decrease global resource efficiency as more metals will be mined
	SDG 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries	Caused by the impacted target 8.1	Increase in revenues in sectors linked to EVs is expected to raise industry's share of employment and GDP
Effect 18: Decreased waste management of ICE engines	SDG 11. Make cities and human settlements inclusive, safe, resilient and sustainable	11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	Decreasing treatment of ICE engines is expected to decrease impact of cities through reduction of waste	The main interlinkage of target 11.6 is with SDG 3 (Good health and well-being) SDG 12 (responsible consumption and production)
	SDG 3. Ensure healthy lives and promote well-being for all at all ages	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Caused by the impacted target 11.6	Decreasing treatment of ICE engines is expected to reduce environmental pollution from recycling operation, thereby decreasing human health impacts
	SDG 12. Ensure sustainable consumption and production patterns	12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment	Caused by the impacted target 11.6	Decreasing treatment of ICE engines is expected to reduce release of chemicals from recycling operations

Appendix B2 – Documentation of evaluation of SDGs-targets impacts (Step 2 of Phase 4)

Table B2. SDG impact evaluation scores of each identified effect based on argued likelihood and magnitude of the effects contribution to SDGs/targets (Extracted from Excel-based tool, which uses scoring system from Table 10).

			Direction	Likelihood	Magnitude	Qualitative contributions	Justification for likelihood	Justification for magnitude
Effect 1:	SDG 3.	3.9	Negative	Likely	Negligible	0	an EV contains approximately twice more rare earth elements when compared to an ICE car, doubling emissions from extraction	Impacts from extraction are not the dominant sources of human health impact in EVs' life cycles
	SDG 12.	12.2	Negative	Likely	Negligible	0	an EV contains approximately twice more rare earth elements when compared to an ICE car, doubling impacts on resources	Impacts from extraction are not the dominant sources of resource-related impact in EVs' life cycles
	SDG 13.	13.1	Negative	Likely	Negligible	0	an EV contains approximately twice more rare earth elements when compared to an ICE car, doubling emissions from extraction	Impacts from extraction are not the dominant sources of climate-related impact in EVs' life cycles
	SDG 6.	6.3	Negative	Likely	Negligible	0	an EV contains approximately twice more rare earth elements when compared to an ICE car, doubling emissions from extraction	There is some, but still very limited evidence that REEs from anthropogenic sources are found in freshwater
	SDG 14.	14.1	Negative	Likely	Negligible	0	an EV contains approximately twice more rare earth elements when compared to an ICE car, doubling emissions from extraction	There is some, but still very limited evidence that REEs from anthropogenic sources are found in coastal and marine waters
	SDG 15.	15.5	Negative	Likely	Negligible	0	an EV contains approximately twice more rare earth elements when compared to an ICE car, doubling emissions from extraction	There is some, but still very limited evidence that REEs from anthropogenic sources are found in soils
Effect 2:	SDG 3.	3.9	Negative	Likely	Negligible	0	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Contribution of extraction operations for mining of REEs to total impact is very small
	SDG 12.	12.2	Negative	Likely	Small	--	Extraction of fossil fuels will inevitably lower amount of accessible stock of fossil resources	Contribution of extraction operations for mining of REEs to total impact is very small
	SDG 13.	13.1	Negative	Likely	Negligible	0	Emissions of GHGs will depend on how clean extraction processes are, although some releases are inevitable	Contribution of extraction operations for mining of REEs to total impact is very small
	SDG 6.	6.3	Negative	Likely	Negligible	0	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Contribution of extraction operations for mining of REEs to total impact is very small
	SDG 14.	14.1	Negative	Likely	Negligible	0	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Contribution of extraction operations for mining of REEs to total impact is very small
	SDG 15.	15.5	Negative	Likely	Negligible	0	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Contribution of extraction operations for mining of REEs to total impact is very small

Effect 3:	SDG 12.	12.2	Negative	Possible	Negligible	0	Production of capital goods and equipment can be partly based on recycled materials	Contribution of capital goods and equipment to total environmental impacts of products is usually very small
	SDG 13.	13.1	Negative	Likely	Negligible	0	There is evidence that production of capital goods and equipment, irrespective of the type of material, is causing CO2 emissions	Contribution of capital goods and equipment to total environmental impacts of products is usually very small
	SDG 3.	3.9	Negative	Possible	Negligible	0	Release of chemicals will depend on how clean manufacturing processes are	Contribution of capital goods and equipment to total environmental impacts of products is usually very small
	SDG 6.	6.3	Negative	Possible	Negligible	0	Release of chemicals will depend on how clean manufacturing processes are	Contribution of capital goods and equipment to total environmental impacts of products is usually very small
	SDG 14.	14.1	Negative	Possible	Negligible	0	Release of chemicals will depend on how clean manufacturing processes are	Contribution of capital goods and equipment to total environmental impacts of products is usually very small
	SDG 15.	15.5	Negative	Possible	Negligible	0	Release of chemicals will depend on how clean manufacturing processes are	Contribution of capital goods and equipment to total environmental impacts of products is usually very small
Effect 4:	SDG 12.	12.2	Negative	Possible	Negligible	0	Production of charging stations be partly based on recycled materials	Contribution from charging stations to total impact is expected to be very small when compared to impact from EV
	SDG 13.	13.1	Negative	Likely	Negligible	0	Production of charging stations, irrespective of the material, will cause CO2 emissions	Contribution from charging stations to total impact is expected to be very small when compared to impact from EV
	SDG 3.	3.9	Negative	Possible	Negligible	0	Release of chemicals will depend on how clean manufacturing processes for charging stations is	Contribution from charging stations to total impact is expected to be very small when compared to impact from EV
	SDG 6.	6.3	Negative	Possible	Negligible	0	Release of chemicals will depend on how clean manufacturing processes for charging stations is	Contribution from charging stations to total impact is expected to be very small when compared to impact from EV
	SDG 14.	14.1	Negative	Possible	Negligible	0	Release of chemicals will depend on how clean manufacturing processes for charging stations is	Contribution from charging stations to total impact is expected to be very small when compared to impact from EV
	SDG 15.	15.5	Negative	Possible	Negligible	0	Release of chemicals will depend on how clean manufacturing processes for charging stations is	Contribution from charging stations to total impact is expected to be very small when compared to impact from EV
Effect 5:	SDG 12.	12.2	Positive	Possible	Negligible	0	Elements of ICE engines can be made from recycled material	Contribution from ICE engines to total impact is expected to be very small when compared to impact from ICE
	SDG 13.	13.1	Positive	Likely	Negligible	0	Production of ICE, irrespective of the material, will cause CO2 emissions	Contribution from ICE engines to total impact is expected to be very small when compared to impact from ICE
	SDG 3.	3.9.	Positive	Possible	Negligible	0	Release of chemicals will depend on how clean manufacturing processes for ICE engines is	Contribution from ICE engines to total impact is expected to be very small when compared to impact from ICE

	SDG 6.	6.3	Positive	Possible	Negligible	0	Release of chemicals will depend on how clean manufacturing processes for ICE engines is	Contribution from ICE engines to total impact is expected to be very small when compared to impact from ICE
	SDG 14.	14.1	Positive	Possible	Negligible	0	Release of chemicals will depend on how clean manufacturing processes for ICE engines is	Contribution from ICE engines to total impact is expected to be very small when compared to impact from ICE
	SDG 15.	15.5	Positive	Possible	Negligible	0	Release of chemicals will depend on how clean manufacturing processes for ICE engines is	Contribution from ICE engines to total impact is expected to be very small when compared to impact from ICE
	SDG 8.	8.1	Negative	Possible	Large	---	Possible loss of GDP and employment capacity in the supply chain of car manufacturing (for all parts dependent on ICE technology), depending on adaptability of the sector (e.g. reconversion)	Contribution may be large for car manufacturing sector
	SDG 9.	9.2	Negative	Possible	Large	---	Possible loss of GDP and employment capacity in the supply chain of car manufacturing (for all parts dependent on ICE technology), depending on adaptability of the sector (e.g. reconversion)	Contribution may be large for car manufacturing sector
Effect 6:	SDG 8.	8.1	Positive	Likely	Moderate	++	Added economic value spurred from the added technology. High likelihood assumed (see Phase 1 arguments for selecting project application)	Contribution may be moderate in the car manufacturing sector (other battery technology production pathways already exist; magnitude will depend on profitability of the new tech and its new technical performances compared to those on market)
	SDG 9.	9.2	Positive	Likely	Moderate	++	Added economic value spurred from the added technology. High likelihood assumed (see Phase 1 arguments for selecting project application)	Contribution may be moderate in the car manufacturing sector (other battery technology production pathways already exist; magnitude will depend on profitability of the new tech and its new technical performances compared to those on market)
	SDG 17.	17.1	Positive	Possible	Small	+	Business opportunities and partnerships between stakeholders in public and private sectors may arise	Small impact as contained with a segment of car industry
Effect 7:	SDG 12.	12.2	Negative	Likely	Negligible	0	Increase of resource demand for battery production will trigger increased demand for specific metals resources	Negligible impacts assumed due to compensating effects of (1) increased draw for mining of metals required, and (2) decreased needs for mining due to incentives creation for recycling/circularity of precious metals
	SDG 13.	13.1	Negative	Likely	Small	--	Additional demand for battery resources will lead to additional energy demand outside DK (hence likely relying on fossils sources)	Contribution may be small as only considering GHG emissions from battery production
	SDG 3.	3.9.	Negative	Unlikely	Large	--	Unlikely releases due to containment measures during manufacturing processes (depending on location of production)	Large impacts as some potential emissions of metals could be severely damaging human health and ecosystems
	SDG 6.	6.3	Negative	Unlikely	Large	--	Unlikely releases due to containment measures during manufacturing processes (depending on location of production)	Large impacts as some potential emissions of metals could be severely damaging human health and ecosystems

	SDG 14.	14.1	Negative	Unlikely	Large	--	Unlikely releases due to containment measures during manufacturing processes (depending on location of production)	Large impacts as some potential emissions of metals could be severely damaging human health and ecosystems
	SDG 15.	15.5	Negative	Unlikely	Large	--	Unlikely releases due to containment measures during manufacturing processes (depending on location of production)	Large impacts as some potential emissions of metals could be severely damaging human health and ecosystems
	SDG 8.	8.1	Positive	Possible	Moderate	++	Added economic value spurred from the added technology. Medium likelihood assumed depending on competitiveness of new technology on the market (with respect to other existing technologies)	Moderate impacts as potential creation of jobs and increase in GDP of sector
	SDG 8.	8.4	Positive	Possible	Negligible	0	Added economic value spurred from the added technology. Medium likelihood assumed depending on competitiveness of new technology on the market (with respect to other existing technologies)	Negligible impacts assumed due to compensating effects of (1) decreased global resource efficiencies due to more mining of metals requried, and (2) increase global resource efficiencies due to incentives creation for recycling/circularity of precious metals
	SDG 9.	9.2	Positive	Possible	Moderate	++	Added economic value spurred from the added technology. Medium likelihood assumed depending on competitiveness of new technology on the market (with respect to other existing technologies)	Moderate impacts as potential creation of jobs and increase in GDP of sector
Effect 8:	SDG 3.	3.9	Positive	Likely	Small	++	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Although total amount of crude oil extracted is large, emissions from extractions are not dominant contributors to total impact
	SDG 12.	12.2	Positive	Likely	Moderate	++	Extraction of crude oil will inevitably lower amount of accessible stock of fossil resources	Total amount of crude oil (not) extracted is large
	SDG 13.	13.1	Positive	Likely	Small	++	Emissions of GHGs during extraction operations are inevitable	Although total amount of crude oil extracted is large, emissions from extractions are not dominant contributors to total impact
	SDG 6.	6.3	Positive	Likely	Small	++	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Although total amount of crude oil extracted is large, emissions from extractions are not dominant contributors to total impact
	SDG 14.	14.1	Positive	Likely	Small	++	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Although total amount of crude oil extracted is large, emissions from extractions are not dominant contributors to total impact
	SDG 15.	15.5	Positive	Likely	Small	++	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Although total amount of crude oil extracted is large, emissions from extractions are not dominant contributors to total impact
Effect 9:	SDG 2.	2.1.	Positive	Unlikely	Small	0	There is ongoing trend of not using food biomass for biofuel production	Effect is considered small because biofuels constitute <10% of total blend
	SDG 12.	12.5	Positive	Possible	Small	+	This effect will depend on the incumbent waste management system for biowaste	Effect is considered small because biofuels constitute <10% of total blend
	SDG 1.	1.2	Positive	Unlikely	Negligible	0	There is ongoing trend of not using food biomass for biofuel production	Reduction in poverty depends on a number of other factors, next to food availability
	SDG 6.	6.3	Positive	Unlikely	Negligible	0	This effect will depend on the incumbent waste management system for biowaste	Contribution from emissions from biowaste to environmental pollution is relatively small compared to other emission sources

Effect 10:	SDG 12.	12.4	Positive	Likely	Negligible	0	Emissions of hydrocarbons will depend on how clean production process is, although some releases are inevitable	Although total amount of fuels is large, emissions from extractions are not dominant contributors to total impact
	SDG 3.	3.9	Positive	Likely	Small	++	Emissions of hydrocarbons will depend on how clean production process is, although some releases are inevitable	Although total amount of fuels is large, emissions from extractions are not dominant contributors to total impact
	SDG 6.	6.3	Positive	Likely	Small	++	Emissions of hydrocarbons will depend on how clean production process is, although some releases are inevitable	Although total amount of fuels is large, emissions from extractions are not dominant contributors to total impact
	SDG 13.	13.1	Positive	Likely	Small	++	Emissions of GHGs will depend on how clean production process is, although some releases are inevitable	Although total amount of fuels is large, emissions from extractions are not dominant contributors to total impact
	SDG 14.	14.1	Positive	Likely	Small	++	Emissions of hydrocarbons will depend on how clean production process is, although some releases are inevitable	Although total amount of fuels is large, emissions from extractions are not dominant contributors to total impact
	SDG 15.	15.5	Positive	Likely	Small	++	Emissions of hydrocarbons will depend on how clean production process is, although some releases are inevitable	Although total amount of fuels is large, emissions from extractions are not dominant contributors to total impact
Effect 11:	SDG 3.	3.9	Negative	Likely	Small	--	Emissions of hydrocarbons will depend on how clean extraction process is, although some releases are inevitable	Although total amount energy sources large, emissions from extractions are not dominant contributors to total impact when seen in EV life cycle
	SDG 12.	12.2	Negative	Likely	Small	--	Extraction of fossil fuels will inevitably lower amount of accessible stock of fossil resources	Total amount of energy sources to be extracted is large when seen in EV life cycle, but little contribution from fossils is expected for the use/operation stage in Denmark (where energy policies prioritise renewables)
	SDG 13.	13.1	Negative	Likely	Small	--	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Although total amount energy sources large, emissions from extractions are not dominant contributors to total impact when seen in EV life cycle
	SDG 6.	6.3	Negative	Likely	Small	--	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Although total amount energy sources large, emissions from extractions are not dominant contributors to total impact when seen in EV life cycle
	SDG 14.	14.1	Negative	Likely	Small	--	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Although total amount energy sources large, emissions from extractions are not dominant contributors to total impact when seen in EV life cycle
	SDG 15.	15.5	Negative	Likely	Small	--	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Although total amount energy sources large, emissions from extractions are not dominant contributors to total impact when seen in EV life cycle
Effect 12:	SDG 12.	12.4	Positive	Likely	Large	+++	Combustion is inevitably associated with emissions of CO2, nitrogen oxides or particulate matter	Use of ICEs and related chemical emissions are by far the most problematic stage of ICE cars' life cycles
	SDG 3.	3.9	Positive	Likely	Large	+++	Combustion is inevitably associated with emissions of CO2, nitrogen oxides or particulate matter	Combustion emissions from ICE cars are an important contributor to human health impacts in ICE cars' life cycles
	SDG 11.	11.6	Positive	Likely	Large	+++	Combustion is inevitably associated with emissions of particulate matter	Emissions of PM from ICE cars are an important contributor to human health impacts
	SDG 13.	13.1	Positive	Likely	Large	+++	Combustion is inevitably associated with emissions of CO2	CO2 emissions from transportation are an important contributor to climate change impacts

	SDG 14.	14.1	Positive	Likely	Small	++	Combustion is inevitably associated with emissions of nitrogen oxides and metals	Nitrogen oxides and metals from car passenger transport are not an important contributor to marine pollution
	SDG 15.	15.5	Positive	Likely	Small	++	Combustion is inevitably associated with emissions of CO2	CO2 is not necessarily the major stressor causing biodiversity loss
Effect 13:	SDG 12.	12.4	Negative	Unlikely	Moderate	-	Unlikely as in DK, where only renewables electricity sources are built for additional capacity (long-term marginal technologies)	Use of EVs and related chemical emissions is bar far the most problematic stage of EVs life cycle
	SDG 3.	3.9	Negative	Unlikely	Moderate	-	Unlikely as in DK, where only renewables electricity sources are built for additional capacity (long-term marginal technologies)	Combustion of fossil fuels is dominant source of human health impacts from power generation
	SDG 11.	11.6	Negative	Unlikely	Moderate	-	Unlikely as in DK, where only renewables electricity sources are built for additional capacity (long-term marginal technologies)	Emissions of PM from power generations cars are an important contributor to human health impacts
	SDG 13.	13.1	Negative	Unlikely	Moderate	-	Unlikely as in DK, where only renewables electricity sources are built for additional capacity (long-term marginal technologies)	CO2 emissions from power generation are an important contributor to climate change impacts
	SDG 14.	14.1	Negative	Unlikely	Small	0	Unlikely as in DK, where only renewables electricity sources are built for additional capacity (long-term marginal technologies)	Nitrogen oxides and metals are not an important contributor to marine pollution
	SDG 15.	15.5	Negative	Unlikely	Small	0	Unlikely as in DK, where only renewables electricity sources are built for additional capacity (long-term marginal technologies)	CO2 is not necessarily the major stressor causing biodiversity loss
Effect 14:	SDG 7.	7.2	Positive	Likely	Moderate	++	Generation of electricity from renewable sources will inevitably increase their share in the energy mix	Wind is expected to be the source of energy used to meet increasing demand in the long term
	SDG 12.	12.2	Negative	Likely	Moderate	--	Metals, including REEs, will be used for production of wind turbines or solar cells	Moderate effect because many metals used in wind turbines and solar cells are currently not recycled
	SDG 13.	13.1	Positive	Likely	Small	++	Generation of electricity from renewable sources will inevitably decrease CO2 emissions	Moderate effect because climate change impacts from renewable energy sources are 1-2 orders of magnitude smaller when compared to fossil fuels
	SDG 6.	6.3	Negative	Possible	Negligible	0	Some emissions of metals from mining material are inevitable	Emissions of metals from mining waste are not important contributor to total impact in EVs' life cycles
	SDG 14.	14.1	Negative	Possible	Negligible	0	Some emissions of metals from mining material are inevitable	Emissions of metals from mining waste are not important contributor to total impact in EVs' life cycles
	SDG 15.	15.5	Negative	Possible	Negligible	0	Some emissions of metals from mining material are inevitable	Emissions of metals from mining waste are not important contributor to total impact in EVs' life cycles
Effect 15:	SDG 3.	3.9	Negative	Likely	Negligible	0	Emissions of hydrocarbons will depend on how clean extraction process is, although some releases are inevitabe	Although total amount energy sources large, emissions from extractions are not dominant contributors to total impact when seen in EV life cycle, and overall effect is proportionally smaller because increase in driving is modest in 10-year time horizon.

SDG 12.	12.2	Negative	Likely	Negligible	0	Extraction of fossil fuels will inevitably lower amount of accessible stock of fossil resources	Total amount of energy sources to be extracted is large when seen in EV life cycle, but little contribution from fossils is expected for the use/operation stage in Denmark (where energy policies prioritise renewables), and overall effect is proportionally smaller because increase in driving is modest in 10-year time horizon,
SDG 12.	12.4	Negative	Unlikely	Small	0	Unlikely as in DK, where only renewables electricity sources are built for additional capacity (long-term marginal technologies)	Use of EVs and related chemical emissions is bar far the most problematic stage of EVs life cycle, but overall effect is proportionally smaller because increase in driving is modest in 10-.year time horizon,
SDG 7.	7.2	Positive	Likely	Small	++	Generation of electricity from renewable sources will inevitably increase their share in the energy mix	Wind is expected to be the source of energy used to meet increasing demand in the long term, but overall effect is proportionally smaller because increase in driving is modest in 10-.year time horizon
SDG 12.	12.2	Negative	Likely	Small	--	Metals, including REEs, will be used for production of wind turbines or solar cells	Many metals used in wind turbines and solar cells are currently not recycled, but overall effect is proportionally smaller because increase in driving is modest in 10-year time horizon
SDG 13.	13.1	Positive	Likely	Negligible	0	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Although total amount energy sources large, emissions from extractions are not dominant contributors to total impact when seen in EV life cycle, and effect is proportionally smaller because increase in driving is modest in 10-.year time horizon
SDG 6.	6.3	Negative	Likely	Negligible	0	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Although total amount energy sources large, emissions from extractions are not dominant contributors to total impact when seen in EV life cycle, and overall effect is proportionally smaller because increase in driving is modest in 10-year time horizon
SDG 14.	14.1	Negative	Likely	Negligible	0	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Although total amount energy sources large, emissions from extractions are not dominant contributors to total impact when seen in EV life cycle, and overall effect is proportionally smaller because increase in driving is modest in 10-year time horizon
SDG 15.	15.5	Negative	Likely	Negligible	0	Emissions of hydrocarbons will depend on how clean extraction processes are, although some releases are inevitable	Although total amount energy sources large, emissions from extractions are not dominant contributors to total impact when seen in EV life cycle, and overall effect is proportionally smaller because increase in driving is modest in 10-year time horizon
SDG 3.	3.9	Negative	Unlikely	Small	0	Unlikely as in DK, where only renewables electricity sources are built for additional capacity (long-term marginal technologies)	Combustion of fossil fuels is dominant source of human health impacts from power generation, but overall effect is proportionally smaller because increase in driving is modest in 10-year time horizon
SDG 11.	11.6	Negative	Unlikely	Small	0	Unlikely as in DK, where only renewables electricity sources are built for additional capacity (long-term marginal technologies)	Emissions of PM from power generations cars are an important contributor to human health impacts, but overall effect is proportionally smaller because increase in driving is modest in 10-year time horizon

	SDG 13.	13.	Positive	Unlikely	Small	0	Unlikely as in DK, where only renewables electricity sources are built for additional capacity (long-term marginal technologies)	CO2 emissions from power generation are an important contributor to climate change impacts, but overall effect is proportionally smaller because increase in driving is modest in 10-year time horizon
	SDG 15.	15.5	Negative	Unlikely	Negligible	0	Unlikely as in DK, where only renewables electricity sources are built for additional capacity (long-term marginal technologies)	Nitrogen oxides and metals are not an important contributor to marine pollution, and overall effect is proportionally smaller because increase in driving is modest in 10-year time horizon
	SDG 13.	13.	Negative	Likely	Negligible	0	Generation of electricity from renewable sources will inevitably decrease CO2 emissions	Climate change impacts from renewable energy sources are 1-2 orders of magnitude smaller when compared to fossil fuels, but overall effect is proportionally smaller because increase in driving is modest in 10-year time horizon
	SDG 6.	6.3	Negative	Possible	Negligible	0	Some emissions of metals from mining material are inevitable	Emissions of metals from mining waste are not important contributor to total impact in EVs' life cycles, and overall effect is proportionally smaller because increase in driving is modest in 10-year time horizon
	SDG 14.	14.1	Negative	Possible	Negligible	0	Some emissions of metals from mining material are inevitable	Emissions of metals from mining waste are not important contributor to total impact in EVs' life cycles, and overall effect is proportionally smaller because increase in driving is modest in 10-year time horizon
	SDG 15.	15.5	Negative	Possible	Negligible	0	Some emissions of metals from mining material are inevitable	Emissions of metals from mining waste are not important contributor to total impact in EVs' life cycles, and overall effect is proportionally smaller because increase in driving is modest in 10-year time horizon
Effect 16:	SDG 11.	11.6	Negative	Unlikely	Negligible	0	Unlikely as in DK, where only renewables electricity sources are built for additional capacity (long-term marginal technologies)	Emissions from slags are not expected to be an important contributors to environmental impacts of cities
	SDG 3.	3.9	Negative	Unlikely	Negligible	0	Unlikely as in DK, where only renewables electricity sources are built for additional capacity (long-term marginal technologies)	Emissions from slags are not expected to be an important contributors to impact on human health from EV life cycles
	SDG 12.	12.4	Negative	Unlikely	Negligible	0	Unlikely as in DK, where only renewables electricity sources are built for additional capacity (long-term marginal technologies)	Emissions from slags are not expected to be an important contributors to environmental pollution from EV life cycles
	SDG 12.	12.5	Negative	Unlikely	Negligible	0	Unlikely as in DK, where only renewables electricity sources are built for additional capacity (long-term marginal technologies)	Waste from slag does not constitute an important source waste when compared to municipal waste
Effect 17:	SDG 11.	11.6	Negative	Possible	Negligible	0	EV batteries will inevitably become waste	Potential emissions from EV batteries are not expected to be important contributions to environmental impact of cities
	SDG 3.	3.9	Negative	Unlikely	Negligible	0	Likelihood difficult to determine because treatment of EV batteries at large scale is currently not done	Emissions from slags are not expected to be an important contributors to impact on human health from EV life cycles

	SDG 12.	12.4	Negative	Unlikely	Negligible	0	Likelihood difficult to determine because treatment of EV batteries at large scale is currently not done	Emissions from slags are not expected to be an important contributors to environmental pollution from EV life cycles
	SDG 12.	12.5	Negative	Likely	Negligible	0	EV batteries will inevitably become waste	Waste from slag does not constitute an important source waste when compared to municipal waste
	SDG 8.	8.1	Positive	Possible	Small	+	Increasing sales of EVs have the potential to contribute to economic growth	Automotive industry is already an important contributor to economic growth
	SDG 8.	8.4	Negative	Possible	Small	-	Increasing demand for EVs will inevitably decrease resource efficiency	There is already increasing pressure on some critical raw materials (e.g. neodymium) used in modern cars, be it ICE or EVs
	SDG 9.	9.2	Positive	Possible	Small	+	Increasing sales of EVs have the potential to contribute to employment within the sector	Automotive industry is already an important contributor to employment
Effect 18:	SDG 11.	11.6	Positive	Possible	Negligible	0	Lowering amounts of ICE engines will inevitably results in decreasing waste generation	Contribution of ICE cars to waste generation is relatively small because steel is recycled
	SDG 3.	3.9	Positive	Possible	Negligible	0	Recycling operations are linked to damages to human health	Impacts from recycling of ICE engines are relatively small contributors to total impact from ICE cars' life cycles
	SDG 12.	12.4	Positive	Possible	Negligible	0	Recycling operations are linked to environmental pollution	Impacts from recycling of ICE engines are relatively small contributors to total impact from ICE cars' life cycles

Glossary

Term	Definition
Application	Concrete application of the expected outcome of the project in socioeconomic systems, i.e. result of transforming the applied research to full-scale deployment/implementation.
Baseline	A situation, where the application would not have occurred (i.e. the project did not exist or did not yield any implementable results). The definition of the baseline situation starts by considering the entire world and then refine the scope boundaries to only include existing products, technologies or services that the application (from the Goal definition phase) can potentially replace and/or impact.
New system	The baseline system with all the effects (= changes or consequences) that occur when the application of the research outcomes is introduced
Effects	Consequences and changes that the application brings to the baseline (thereby transforming it into the new system); they can be of very diverse nature: physical, economic, social, ethical, etc.
Direct effects	Direct changes – typically intended – from implementing the application in society. They reflect the purpose of the project and its application, and tend to be limited to the main products, technologies or sectors targeted by the application
Indirect effects	Consequences – often unintended – that the application implementation has on other products, technologies or systems than the systems targeted by the application. Indirect effects may include rebound effects, e.g. efficiency increase that reduces specific product or service costs, itself causing a rising demand, which lead to overall larger consumption, thus canceling out the original savings (cf. Jevons paradox).
Process	An element of the life cycle, for which input and outputs can be quantified in the form of energy, materials or resources (for inputs) and products, waste or emissions (for outputs). It typically refers to a physical activity and can represent a single specific activity, e.g. rolling of steel, or a larger entity, e.g. an entire facility that contains many different processes
Life cycle	Systemic view of any predefined entity (product, service, organization, country, etc.) that includes all interlinked stages of its life with all the processes that are drawn upon. The life cycle is typically divided into four stages, each potentially comprising many individual processes: (i) extraction of raw materials necessary to the materials manufacture, (ii) production and/or setting up of the entity, (iii) use or operation of the entity, and (iv) end-of-life (disposal or recycling).
SDG impact	The consequence or contribution that an effect has for an SDG or some of its underlying targets. Both negative and positive contributions are considered alike with the term “SDG impact”. Both negative and positive contributions are considered alike with the term “SDG impact”.
Environmental impact	Impacts that an entity has (or may have) on ecosystems, human health and/or natural resources. They can be related to known environmental problems like climate change, particulate matter formation, chemical pollution, eutrophication, water stress, land use, etc. While SDG no. 13 (climate change) targets one type of environmental impact or SDG no. 15 (Life on land) combines multiple environmental impacts like acidification, photochemical ozone formation, land use and toxic impacts on land ecosystems.