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# Assessing the sustainability implications of research projects against the 17 UN sustainable development goals

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ABSTRACT

Technology has an important role to play in the development of a sustainable society, and technical research is fundamental to ensure the advancement of technologies that is required to achieve the needed progress in eco-efficiency and social performance of future technologies. Sustainability contributions should thus be an important consideration in the development and assessment of technical research but how can we assess the sustainability implications of technical research projects? The paper presents a new methodology taking a life cycle perspective on the potential technological and societal changes resulting from research projects and assessing their sustainability implications against the United Nations' 17 sustainable development goals (SDGs). It provides information about both positive and negative contributions to the SDGs and support identification of improvement potentials as input to the research project.



## 1. Introduction

Sustainability is increasingly integrated into decision- and policy-making processes. This is reflected in the development of the Sustainable Development Goals (SDGs), accepted by all Member States of the United Nations (UN) in 2015. The SDGs consist of 17 goals, complemented with 169 targets, which together specify a 2030 development agenda to reach sustainable societies (UN 2015).

In that setting, the consideration of sustainability metrics when developing products, technologies and services is essential (Hauschild, 2015, Laurent et al., 2019). Life cycle assessment (LCA) is an ISO-standardized methodology, which can help facilitate that process, as it enables to quantitatively assess the environmental impacts of products and services in a life cycle perspective, i.e. from raw materials extraction, through production and use, up to end-of-life (ISO 2006). The thus-determined life cycle environmental impact indicators can inform about eco-efficiency (or relative sustainability). The assessment results can support the design and development of new products and technologies to decrease potential environmental impacts (Hauschild, 2015).

LCA, primarily focusing on specific product or technology development, has limitation in its applicability and in its ability to gauge the sustainability implications at societal level. Existing assessments often are limited to addressing impacts from specific dimensions of sustainability, and rarely manage to address all three pillars –environmental, social, economic. Operational methods to assess all SDGs are hence lacking. Moreover, although some methods have been proposed to assess impacts arising from some types of projects (Maier et al., 2016), they are difficult to operationalize and apply to research projects (e.g. research on organizational change in companies), for which a prospective approach is required. Being at the stem of product, technology or service development, research projects are an essential place to anticipate and prevent impacts impeding sustainability. Methods to assess such impacts of research projects, e.g. in relation to SDGs, need to be developed.

In this study, we propose such a methodology for performing a screening assessment of the sustainability of research projects, relying on the UN SDG framework to cover all dimensions of sustainability. We use a case study of a research project developing a circular economy solution for companies as a proof-of-concept.

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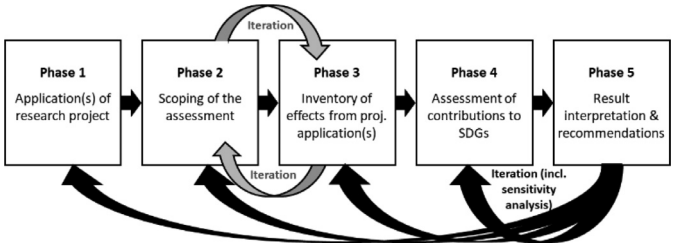


**Fig. 1.** Screening SDG assessment methodology for projects

## 2. Proposed assessment methodology

The methodology is structured into 5 phases –see Fig. 1. The theoretical foundation of each phase is explained in the subsequent sections. It is inspired from the GHG Protocol's "Project Protocol" standard (also: ISO14064–2:2006) (The Greenhouse Gas Protocol 2006) and the ISO standard on Life Cycle Assessment (ISO14044:2006) (ISO 2006). Much wider scopes are considered here as the methodology covers all sustainability dimensions (not just greenhouse gas emissions) and any projects that may reach out to systems at societal level.

### *2.1. Phase 1: Defining application(s) of the research project*

The aim of Phase 1 is to identify and define the potential societal or technological applications of the research project under study.

The difficulty of this task varies from projects to projects, as some may focus on a concrete product or technological solution that is intended to be directly implemented in society at the project end (i.e. typical applied science projects), whereas others can be basic scientific research projects that may lead to practical and sometimes indirect applications in the future. In this phase, the analyst therefore needs to identify the expected outcome of the project and foresee its most likely concrete application in socioeconomic systems.

Some projects may have several possible applications and ideally, they should all be considered to reflect the potential impacts of the project outcomes on society and environment, and ultimately the contributions to meeting the SDGs. Prioritization may be done to simplify the task, focusing on the application(s) with the highest probability to enter the market and/or with the largest potential impact on the SDGs. Likewise, it may be useful to delimit the scope of the application, for example to a specific country, region or sector, to make the assessment more manageable. Again, the combination of probability and impact should guide the delimitation.

The ability to predict which application(s) will actually take place and to what extent they will be effective is limited. The choice of considered application(s) may therefore be subjective and accompanied by large uncertainties. Beyond a transparent documentation and justification of these choices, a sensitivity analysis can be performed 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 underlying the methodology, where it is recommended to revisit and refine the assessment in each of the methodological steps (Fig. 1).

The temporal dimension of the application is also important to evaluate, as some applications may be associated with delayed implementation or long-term effects on society (e.g. technology developed today may show potentials much later, etc.). While the evaluation of the contribution of a project to sustainable development should ideally be time-independent and have an infinite time horizon, in this methodology, the assessment may be limited to effects up to 2030. This choice 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.

### *2.2. 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". This perspective is analogous to assessment of GHG emission mitigation projects (The Greenhouse Gas Protocol 2006).

Phase 2 includes two steps, aiming at defining the assessment boundaries of the baseline and new systems. 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 of existing products or technologies with improved ones). In 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.

#### *2.2.1. Step 1. Delimiting the assessment boundary of the baseline*

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 limitation). 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. 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. Hence, differentiation between the four life cycle stages 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. 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 rea-

son why we recommend that Phases 2 and 3 be done in iteration (see Fig. 1), 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.

#### 2.2.2. Step 2. Delimiting the assessment boundary of the new system

In situations, where the new system fulfil 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, etc.). In the rare cases, where both systems fulfil different needs/functions, the baseline (prior to removal of insignificant activities) is simply the whole world without the new application, as it evolves from now into the future, 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.

### 2.3. Phase 3: Inventorying effects from project applications

The "effects" are consequences and 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.

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). Effects can be direct changes from implementing the application in society. In applied science projects, they are typically intended effects, reflecting the purpose of the project and its application, and tend to be limited to the main products, technologies or sectors targeted by the application. Effects can also be indirect and unintended, being the consequences of the application implementation on other products, technologies or systems than the systems targeted by the application.

### 2.4. Phase 4: Assessment of contributions to SDGs

Phase 4 is divided in two steps aiming at (i) identifying the SDGs that may be affected by the effects, i.e. connecting the effects to their potential consequences on the goals and targets of the UN SDG framework, and (ii) performing a semi-quantitative evaluation of the contribution of the effects to SDGs.

#### 2.4.1. Step 1. Identify 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.

Various methods may be used for performing such connections or linkages, and there is no one-size-fit-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. 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 on socioeconomic systems and on the environment. For such analysis, the causal chain approach may be useful, as it links an action or a change to its consequences through a series of logic and sequential interlinked cause-effect relationships, e.g. use for environmental impact pathway modelling in life cycle impact assessment (Rosenbaum et al., 2018)). A number of other tools exist that may help link the effects to the different SDGs and targets, e.g. ref. (WBCSD 2018, United Nations Global Compact 2018, United Nations Global Compact 2019, PWC 2019).

Both positive and negative impacts on the SDGs and targets should be identified, encompassing all 17 SDGs and shortlisting the relevant ones. It is noteworthy that numerous interlinkages exist between the SDGs and their targets, meaning that a negative contribution to an SDG X may induce a negative contribution to another SDG Y and counterbalance a pre-identified positive contribution to SDG Y. Such interlinkages should be captured as much as possible in the evaluation, e.g. with existing online tools (Institute for Global Environmental Strategies 2019, ICSU 2017).

#### 2.4.2. Step 2. Evaluate the contribution to SDGs

The evaluation of the new system's contribution to the SDGs can be conducted qualitatively or quantitatively. Quantitative assessment can 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.; (WBCSD 2018, United Nations Global Compact 2018, United Nations Global Compact 2019, PWC 2019)). It means that a full quantitative evaluation covering all SDGs is currently not possible. In this methodology, a semi-quantitative assessment is proposed to characterize the extent of the contributions of each effect from the application to the SDGs (also termed "SDG impacts" here).

The assessment should consider the following three criteria:

- Whether the contribution is positive or negative (or negligible/unknown).
- Likelihood that the SDG impacts will occur (based on objective evidence to the extent possible). Graded as: likely – possible – unlikely.
- Magnitude of the SDG impacts. Graded as: major – moderate – minor.
- Based on the correspondence matrix in Table 1, a 5-grade evaluation (++, +, 0, -, –) can be derived.

### 2.5. Phase 5: Interpretation

Through Phases 1–4, the contribution of a project and its considered application to the SDGs can be gauged, and analyses can

**Table 1**
Evaluation scoring matrix.

| Scoring | Contribution | Likelihood | Magnitude |
|---|---|---|---|
| ++ | Positive | Likely | Major or Moderate |
| + | Positive | Likely | Minor |
| | | Possible or Unlikely | Major or Moderate or Minor |
| 0 | Negligible or Unknown | Unlikely | Minor |
| | | Unknown | None or Unknown |
| - | Negative | Possible or Unlikely | Major or Moderate or Minor |
| | | Likely | Minor |
| – | Negative | Likely | Major or Moderate |

be made to identify possible hotspots for improvements (i.e. parts in the system life cycle, where large negative contributions to the SDGs are caused) and trade-offs between SDGs (when the application leads to positive contributions for some SDGs and negative ones 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) and be potentially integrated into the research project to support mitigation actions.

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 (positive or negative)? Where do they occur, i.e. in which life cycle stage(s) and what causes them? For each 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 or different scoping considered, or where the analysis of the baseline and the new system defined in Phases 1 and 2 is revisited and refined to improve the certainty for some of the central assumptions. Such iterations are fundamental for the effective use of the methodology (Fig. 1).

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 lead to possible recommendations on how to improve the SDG performances of a specific project application. These recommendations can be divided between short-term and long-term recommendations. The former are addressed to stakeholders conducting the project, and may include shortlisting of specific applications or technologies in the project, considerations to integrate into product/technology/ system development to better contribute to SDGs (e.g. eco-design implementation), etc. Long-term recommendations target stakeholders in charge of implementing the project results into the society, i.e. translating the output of the project into concrete applications.

## 3. Proof of concept: Project developing means to analyze circular economy initiatives in the manufacturing sector

The case is an actual PhD project at the Technical University of Denmark, aiming at conceptualizing, developing, validating and implementing a framework to assess the potential sustainability performance of Circular Economy (CE) initiatives applicable to a manufacturing context (Kravchenko et al., 2019). Assessment of the contribution of this research project to the SDGs is summarized below to illustrate the application of the proposed methodology.

### *3.1. Phase 1: Application of the project*

The research projects aims at developing a consolidated database of leading performance indicators to be used for sustainability screening of CE strategies in manufacturing companies. This would allow analyzing the potential economic, social and environmental performances of circular solutions in the early stages of the decision-making process (Kravchenko et al., 2019). Furthermore, a guideline will be developed to support a systematic selection of suitable indicators depending on the type, nature and context of circular economy solution implementation.

The application of the project therefore assumes the implementation of those expected outcomes of the project in manufacturing companies, i.e. a decision-support tool, including database/suite of performance indicators, together with its implementation guidelines.

For the assessment, a specific application of companies manufacturing furniture (i.e. secondary manufacturing) is considered, with a limitation of the geographical scope to those in the Nordic region. The use of the tool is expected to lead to changes in the organizational procedure of companies, from 'assumptive' to a more systematic and informed decision making, leading to the selection of more sustainable (circular or non-circular) options, with focus on recycling increase.

### *3.2. Phase 2: Scoping the assessment*

#### *3.2.1. Step 1. Baseline*

The baseline is defined as the current landscape of furniture-manufacturing companies in the Nordic region. It is assumed that some already have implemented circular economy (CE) solutions, while others did not. Furniture can be assumed to be produced from mix of wood, metal and plastic materials, where part of them can be sourced to recycled materials. Following guidance in Section 2.2, those manufacturing activities are taken in a life cycle perspective to map the life cycle of furniture. The resulting assessment boundary is described in table format in Table 2.

#### *3.2.2. Step 2. New system*

The project application (identified in Phase 1) is expected to result in a new system, where more furniture manufacturing companies from the baseline that previously had not implemented CE solutions would then transition to circular economy solutions (assuming better performances of the latter), and that companies, which already had CE solutions would get more organizationally-optimized (e.g. more eco-efficiency).

Changes in the organizational structure of the furniture-manufacturing companies, and its implications on the value chain of the furniture should thus be envisioned. Yet, although some specific processes in the life cycle of the furniture (e.g. recycling processes) may change, the same functions or services as in the baseline will still be in place in the new system (i.e. same supply of furniture to match an assumed unchanged market demand). Table 2 therefore can still overall apply to describe the new system (note

**Table 2**
Main activities in life cycle of furniture.

| Raw Materials | Production | Use | End-of-life |
|---|---|---|---|
| Wood cutting/ logging<br>Mining of fossil fuels<br>Mining of metal ores | Production of chemicals, additives, paints, etc.<br>Production of plastics<br>Production of metals<br>Processing of wooden, plastic and metallic parts (incl. use of recycled materials)<br>Assembly and packaging of furniture | Maintenance (repair, painting, cleaning) | Dismantling of furniture<br>Incineration of furniture elements (with possible energy recovery and handling of slags)<br>Recycling of furniture elements |

**Table 3**
Effect characterization for furniture-manufacturing companies (E=Effect)

| Raw Materials | Production | Use | End-of-life |
|---|---|---|---|
| ***Physical changes*** | | | |
| Decreased virgin plastic production leading to decreased mining of petroleum products (E1)<br>Decreased virgin wood consumption (E2)<br>Decreased metals mining (E3) | Increased installation capacity and energy & materials consumption for remanufacturing and handling of recycled materials (E4)<br>Added production of new materials with better properties (e.g. fibres) (E5)<br>Decreased processing of virgin metals and virgin plastics (E6) | (assumed no significant effects and same demand between baseline and new system) | Increased collection, transport and recycling efforts of plastic, wood and metal waste, leading to new installed capacity and associated energy & materials consumption. (E10)<br>Decrease in energy recovery from plastic and wood waste incineration in Nordic region (e.g. DK), leading to increased supply from conventional sources (incl. fossils) (E11) |
| ***Non-physical changes*** | | | |
| | Increase image reputation for furniture manufacturer and cost effectiveness (E7)<br>Increase sustainability awareness in employees (E8) | Increased customer satisfaction & awareness from access to more sustainable furniture (E9) | |

that for space constraints, differences in specific processes are not shown here; these are however captured in Phase 3).

### 3.3. Phase 3. Inventory of effects.

Starting from the assessment boundaries defined in Phase 2, effects can be identified. The project application is expected to lead to an increase in number of furniture-manufacturing companies switching to CE solutions and to more optimized organization within companies already using CE solutions, hence strengthening their material circularity. Table 3 reports effects that can be identified from such consequences.

### 3.4. Phase 4: Evaluation of the SDG contribution

SDG impact evaluation scores were determined for each identified effect based on (i) the relevance of each SDG for the considered effect (i.e. impacted or not/negligibly); (ii) likelihood and magnitude of the effect contribution to each SDG and associated targets, where relevant. Results are displayed in Fig. 2. The full background documentation behind the scoring could not be shown for space constraints, but are available upon request to the authors. An illustrative example is the decreased mining and wood cutting activities, which cause reduced environmental and human health impacts from land use, water contamination, etc. (SDG 3,6,13–15 are therefore graded with positive contributions in the raw materials stage) but also lead to decreased economic performances in those sectors (SDG 8–9 graded with negative contributions).

### 3.5. Phase 5: Interpretation

Figure 2 illustrates that the project application has main contributions to SDGs related to environment (SDG 12–15) and economy/industry (SDG 8–9, 17). It primarily contributes to the SDGs in its production (and raw materials) and end-of-life stages, which is consistent with the increased and optimized use of CE solutions. The prevention of waste and reductions in materials consumed are

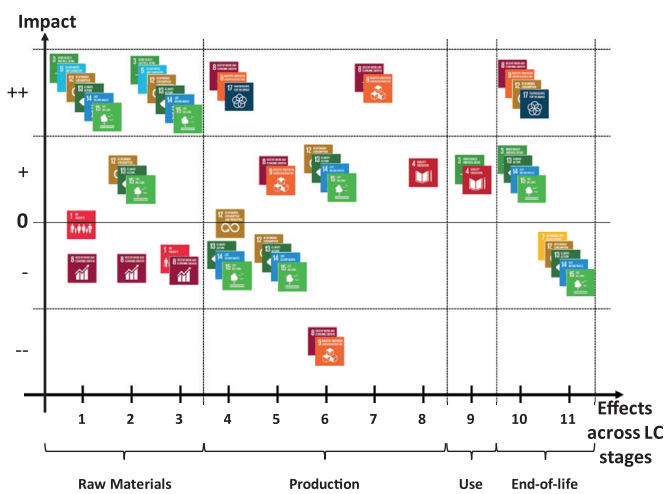


**Fig. 2.** Visual representation of SDG impact screening for the project.

expected to induce environmental benefits in these stages. Business opportunities and economic value are expected for the furniture manufacturing branch and for waste management industries (recycling). Opposite trends may be anticipated for the raw materials processing companies (e.g. mining), depending on the uptake of global metals and plastics by the Nordic furniture branch. Trade-offs between SDGs thus can be observed across and within life cycle stages.

Based on the results, negative impacts on SDGs should be addressed, in particular: (i) quantifying to what extent the raw materials sector may be economically impacted by the CE solutions implementation in the furniture manufacturing sector; and (ii) assessing the environmental trade-offs between the impacts from the increased use of material recovery processes and the saved impacts from processing less virgin materials and avoiding waste landfilling and incineration. LCA can be used for addressing the latter, so the

project and its future applications can better contribute to meeting the SDGs.

From a project perspective, sensitivity analysis should also be used to test other manufacturing sub-sectors and mitigate the possible product/subsector specificities observed in the results (e.g. several raw materials processes are specific to furniture life cycles and may not occur in other subsectors, e.g. services). This also demonstrates that large uncertainties can stem from the definition of the goal and application of the project, and not just in the SDG evaluation phase.

## 4. Operability

The proof-of-concept described in Section 3 demonstrates the applicability of the methodology, which has until now been used in teaching modules for assessing ca. 100 PhD projects in various fields. There, the methodology was only applied at a screening level, requiring approx. 1–2 week workload to conduct. Sufficient knowledge and maturity in the project are necessary, e.g. in Phase 1 to identify relevant application(s).

More detailed assessments could be performed depending on the depth of the investigation (e.g. selection and scoping of application(s) in Phase 1), the extent of Phase 2 (e.g. use of detailed prospective modelling to foresee evolutions of the baseline and new systems), the comprehensive coverage of all impacted SDGs and their interlinkages in Phase 4. These would require more resources and expert knowledge, e.g. involvement of experts in system dynamics, social sciences, technology foresight, economics, etc. Along with tools already available online (e.g. ref. (Institute for Global Environmental Strategies 2019, ICSU 2017)), tools should be developed to facilitate the application of the methodology, e.g. Excel tool to operate the evaluation step in Phase 4.

## 5. Conclusions and Outlook

Although applicable, the methodology carries a number of uncertainties and limitations, relating to the choices made in Phase 1, the comprehensiveness of the mapping and effect identification in Phase 2 and 3 and in the semi-quantitative nature of the evaluation Phase 4, which also does not solve weighting and aggregation challenges within and across SDGs. Those limitations are difficult to overcome owing to the wide scoping of the assessment – covering all sustainability aspects and their potential trade-offs – and to the large diversity of research projects. Current efforts are ongoing to address them.

In its current form, the proposed methodology can therefore be regarded as a screening SDG assessment methodology for research projects, where it may provide some useful insights with a minimum of efforts and can help foresee specific hotspots in the future exploitation of the project so they can be addressed and integrated in the course of the project.

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