Pre-publication Preview

UNEP

SETAC

Life Cycle Initiative

Global Guidance for Life Cycle Impact Assessment Indicators

Volume 1

United Nations Environment Programme

Life Cycle Initiative

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Global Guidance for Life Cycle Impact Assessment Indicators

Volume 1

Acknowledgements

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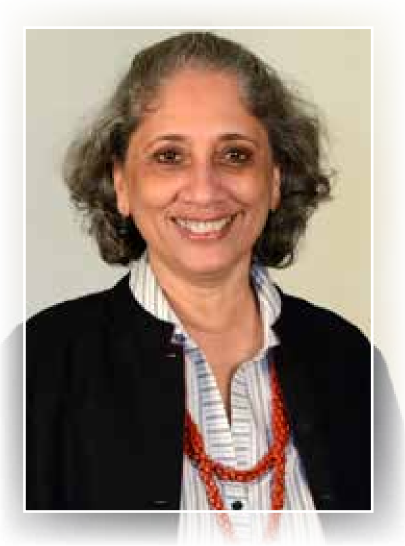


Foreword - UN Environment

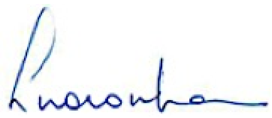
Life cycle assessment is recognized as the most robust tool to provide the systems perspective required to accelerate the shift towards more sustainable consumption and production patterns. It does so by enabling the comparison between product systems (e.g. definition of "green" vs. "conventional" products), and the identification of the main hotspots driving impacts in such systems as well as of potential trade-offs among them. Indicators that clearly show the links between human interventions and environmental impacts are needed. But the pathway from human interventions to impacts can be complex, with diverse indicators being used to capture results. This reduces the comparability between studies, limiting the definition of clear preferences between products and practices, as well as the usability of results.

The *Global Guidance for Life Cycle Impact Assessment Indicators: Volume 1* goes a long way to addressing these issues. Aimed at life cycle assessment practitioners and method developers, it identifies the "current best available practice" in a variety of areas: climate change, human health impacts of fine particulate matter, water use impacts, and land use impacts on biodiversity. The global importance of these impact areas is also recognized in specific Sustainable Development Goals (SDGs).

By building consensus on indicators to represent these important impact areas, this guidance document enhances the comprehensive and consistent assessment of impacts in production and consumption systems throughout their life cycle, making explicit any potential trade-offs and supporting more sustainable processes. It provides a significant leap forward in the environmental representation and accuracy of the proposed indicators, and provides enhanced comparability among studies based on internationally endorsed, scientifically robust, and stable indicators.

The guidance is also a milestone for the UN Environment/Society for Environmental Toxicology And Chemistry Life Cycle Initiative: it positions the Initiative as a global body for the stewardship of impact assessment methods, delivering much-needed consensus-building among method developers and users. More practically, it provides the necessary access to indicators so that life cycle assessment users can incorporate them in their studies. With this publication the Initiative adds to its relevant reference documents, which have contributed to raising global awareness and capacity in life cycle approaches.

With further research and continuous improvement by the Life Cycle Initiative, these indicators will make a valuable contribution in the relevance and comparability of life cycle assessment studies, and they will ultimately enhance the accuracy of the measurement of achievement of the Sustainable Development Goals at the global level.



Ligia Noronha
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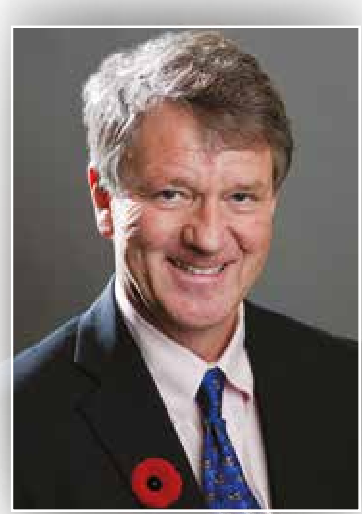
Foreword - SETAC



It is rewarding to witness the increased use of life cycle assessment (LCA) to guide decisions regarding the emergence and use of new products and technologies. As Global Executive Director for the Society of Environmental Toxicology and Chemistry (SETAC), I am well aware of the keen interest in the methodologies that have emerged from the Life Cycle Initiative (LCI), a creative and impactful effort fostered through the collaboration of SETAC and the United Nations Environmental Program (UNEP). LCA-related programs are now a part of all five of SETAC's Geographic Units: Europe, North America, Asia/Pacific, Latin America, and Africa. We have made our collaboration with UNEP a priority as evidenced by the dedication of our staff and members to LCA-related activities.

The benefits of LCA and life cycle thinking are clear. It is natural for people to view any product or technology with respect to narrow sets of benefits and costs that impact them personally. However, that narrow focus can easily miss and often diminish a broader vision of the overall environmental and health footprint. LCA helps guard against this form of myopia and enables decision makers, the public, and other stakeholders to visualize and better understand the overall profile of a particular product or technology. The shared understanding that comes with a common vision is central to fostering informed dialogues and clear pathways toward decisions that involve the various parties who may benefit and/or be affected by a product or technology. For this reason, SETAC will continue to make LCA a central component of a framework to promote the use of science and engineering to inform policy and decisions.

SETAC environmental and health scientists and engineers have focused primarily on the methodological aspects of LCA as part of the Life Cycle Initiative. While methodologies have been developed and applied with respect to the structure and functionality of LCA, it is prudent to track emerging issues that come from the learnings gained from applications and from knowledge concerning the diversity of products, technologies, and geographies for which LCA is sought as an instrument to guide decisions. In particular, the subject matter of this report is central to SETAC science. As someone that has worked in the risk assessment field for four decades, I know that methodologies continue to be updated and refined as new information emerges. And, it is my hope that there can be a convergence among methodological frameworks such as LCA and risk assessment. I share this thinking with other LCA and risk assessment practitioners. Such thinking is consistent with the growing emphasis being given to integrated assessments. As a result, I am very excited about the promise that LCA offers and the opportunity for SETAC to continue to engage with the Life Cycle Initiative to provide insights into what the future holds for the LCA approach and topical areas for applications. We are also pleased that the SETAC Pellston Workshop® format, with its rigor and well-recognized value in scientific advancement, continues to be employed by the Initiative in its work.

This document contains a reservoir of useful and practical information that reflects the dedicated effort and collaboration of many scientists, engineers, and LCA practitioners from around the globe. It should be on the physical and electronic desktops of practitioners as well as those that will benefit from and make use of the outputs of LCA.

I extend my thanks to UNEP for our successful collaborations and look forward to a continued working relationship to help promote and advance this important field of assessment. I want to thank Bruce Vigon of the SETAC staff for all of his efforts.

Charles Menzie, Ph.D.
Global Executive Director
SETAC

Executive summary

Background

Reducing the pressure on the environment related to consumption and production in human systems was identified as a priority in the 2030 Agenda for Sustainable Development by the heads of state and government, and requires the development of products and services with reduced impacts to human health and the environment. In this sense, guidance is needed on which quantitative and life cycle-based indicators are best suited to quantify and monitor man-made impacts on climate change, biodiversity, water resources, and other aspects of the biophysical environment.

Approach

In order to enhance consensus on environmental life cycle impact assessment indicators, the UNEP/SETAC Life Cycle Initiative launched a global process in 2013 focusing on four environmental topics that were selected based on their perceived environmental or political relevance, the maturity of available quantitative indicators, and the chance for reaching consensus. The goal was to reach consensus on recommended environmental indicators and characterization factors for life cycle impact assessment (LCIA) in the areas of 1) global warming, 2) fine particulate matter effects on human health, 3) water use impacts (both scarcity and human health impacts), 4) land use impacts on biodiversity, as well as 5) overall LCIA framework and crosscutting issues. International task forces worked over 24 months focusing their work on those four topics, and progress was reviewed in stakeholder engagement events around the world. White papers were prepared for each area, and previously published information was extracted into a repository for use in preparing these papers and for consultation during a final expert workshop (Pellston workshop[R]) held 24-29 January 2016 in Valencia, Spain. To ensure the validity of this guidance, workshop participants were selected for their technical expertise as well as their geographic representation and their perspective in the "life cycle thinking universe." The final mix of participants consisted of a balance of domain experts from the five topical tracks: life cycle impact assessment method developers, providers of life cycle thinking studies (primarily consultants and industry associations), and users of life cycle information, including governmental and intergovernmental organizations (IGOs), government, industry, nongovernmental organizations (NGOs), and academics.

The workshop participants emphasized developing and harmonizing environmental impact category indicators. Their discussions maintained a balance between scientific rigor and practicality to ensure the environmental indicators were credibile, applicable, and easily understood by non-scientists. It was important to bridge the gap between domain experts and indicator developers concerned with scientific complexity on one hand and users, who wanted simple, meaningful, and well-tested environmental indicators, on the other. Participants carefully defined appropriate goals and scopes for the developed indicators, and developed a glossary of terminology to enhance understanding and provide a consistent reference.

Summary results

The participants of the Pellston Workshop[R] agreed on tangible and practical recommendations on environmental indicators, including substantial innovations. The following are the main recommendations agreed upon.

Life Cycle Impact Assessment framework: The overall framework was slightly revised and now distinguishes between intrinsic, instrumental and cultural values and the damage categories human health and ecosystem quality (intrinsic), socio-economic assets, natural resources and ecosystem services (instrumental) as well as cultural and natural heritage (cultural).

Damage category indicators: The recommended damage category indicators are disability adjusted life years (DALY, human health) and biodiversity loss, including measures of vulnerability (ecosystem quality). No specific damage category indicator is recommended for natural resources and for ecosystem services at this point.

Climate change impacts: We recommend using two climate change impact categories, one representing impacts on the decadal-scale (shorter term) and another for the century-scale (longer term) impacts. The metrics from the 5th IPCC assessment report to be used are the Global Warming Potential 100 year (GWP 100) and the Global Temperature change Potential 100 years (GTP 100), respectively. We recommend using the metrics including climate-carbon cycle feedbacks for all climate forcers (so far only included for CO_2) and addressing the climate change impacts of near term climate forcers including short-lived greenhouse gases in sensitivity analyses, where GWP20 can also be used as an alternative metric for shorter-term impacts.

Fine particulate matter health impacts: Recommended characterization factors (CFs) for primary PM2.5 and interim recommended CFs secondary PM2.5 are established, which distinguish between archetypes for rural and urban areas and for indoor and outdoor emission and exposure settings. Outdoor CFs further distinguish between different emission stack heights.

Water use impacts: The impact categories for both potential ecosystem and human deprivation were discussed and further developed by the task force. Recommended CF for impacts assessing DALYs from malnutrition caused by lack of water for irrigated food production at the damage level as well as for addressing generic potential impacts of water consumption via water scarcity resulted, The native resolution of both methods is on watershed and monthly levels, but for practicability on background LCI, CF are provided also aggregated on annual, country, and global levels.

Land use impacts: CFs representing global potential species loss from land use are proposed as an interim recommendation, suitable to assess impacts on biodiversity due to land use and land use change in hotspot analyses in LCA only (not for comparative assertions nor eco-labeling). Further testing of the CFs as well as the development of CFs for further land use types are required to provide a full recommendation.

Additional crosscutting issues: Several recommendations and suggestions were formulated covering the topics of transparent reporting, reference states, spatial differentiation, uncertainties, time horizons, as well as handling of negative CF values.

Outlook and roadmap

The recommended environmental indicators should not be seen as static, but rather evolutionary and representing the current best available knowledge and practice. It is strongly recommended that the UNEP/SETAC Life Cycle Initiative fosters the momentum of cooperation and establishes a community of LCIA researchers who care for the stewardship of the recommended indicators. The community will grow with the launch of consensus finding processes for the second set of environmental impact indicators (acidification & eutrophication, human and eco-toxicity, mineral resource depletion, and ecosystem services). Spatially differentiated indicators like the ones for land use and water use call for smart and parsimonious approaches from the knowledge gained in LCA research projects in which a high geographic resolution is applied. Finally, the United Nations' Sustainable Development Goals and the concepts of planetary boundaries may profit from the work performed in this flagship project. The recommended environmental indicators may be used to quantify and monitor progress towards sustainable production and consumption.

Resumen ejecutivo

Antecedentes

Garantizar modalidades de consumo y producción sostenibles ha sido identificado como una prioridad en la Agenda 2030 para el Desarrollo Sostenible. En este sentido para una mejor gestión de la problemática ambiental, se hace necesario disponer de indicadores consensuados de ciclo de vida para optimizar la cuantificación y monitoreo de los impactos humanos sobre distintas categorías de impacto ambientales: cambio climático, pérdida de biodiversidad, sobreexplotación de recursos de agua, etc.

Enfoque

Con el fin de mejorar el consenso sobre los indicadores de evaluación de impactos ambientales de ciclo de vida, la UNEP/SETAC Life Cycle Initiative emprendió, en el año 2013, un proceso centrado en proporcionar guía en la utilización de indicadores ambientales, seleccionados en función de su relevancia medioambiental y política, así como de la madurez y disponibilidad de los indicadores cuantitativos existentes. El objetivo era llegar a un consenso sobre los indicadores ambientales y factores de caracterización recomendados para la Evaluación de Impactos del Ciclo de Vida (EICV) en las categorías de impacto de: 1) calentamiento global, 2) efectos en la salud humana de emisiones de micropartículas, 3) los impactos del uso del agua (tanto la escasez como impactos sobre la salud humana), 4) impactos del uso de la tierra sobre la biodiversidad, así como 5) marco general de LCIA y temas transversales. Grupos de trabajo internacionales trabajaron durante más de 24 meses centrándose en esos cinco temas, el progreso se revisó en eventos de consulta con partes interesadas alrededor del mundo. Con la información recopilada se prepararon libros blancos para cada área, que sirvieron de base en el taller de expertos final (Pellston WorkshopTM) celebrado en Valencia (España) del 24 al 29 de enero de 2016. Para asegurar la validez de esta guía, se seleccionaron los participantes del taller por sus conocimientos técnicos, así como su representación geográfica y su probada experiencia alrededor del enfoque de "ciclo de vida". La composición final de los participantes ofrece un equilibrio de expertos en el dominio de los cinco temas objeto de debate, creadores de métodos de evaluación de impactos en el marco de los estudios de ciclo de vida, proveedores de estudios de análisis de ciclo de vida (principalmente consultores y asociaciones industriales), junto con los usuarios de la información de ciclo de vida, incluidas organizaciones gubernamentales e intergubernamentales (OIG), gobiernos, industria, organizaciones no gubernamentales (ONG) y académicos.

Se hizo hincapié en el desarrollo y la armonización de los indicadores de categoría de impacto ambiental. Las discusiones mantuvieron un equilibrio entre el rigor científico y el sentido práctico para asegurar así la credibilidad, la aplicabilidad y la facilidad de comprensión de los indicadores por parte de no expertos. Se tuvo especial cuidado en aproximar, por un lado, la complejidad científica reclamada por los expertos, y la demanda por parte de los usuarios de indicadores simples, útiles y bien probados por el otro. Así mismo se definieron cuidadosamente el objetivo y alcance para los cuales se consideran apropiados los indicadores desarrollados. Para mejorar la comprensión, uno de los ejercicios del taller fue desarrollar un glosario de términos para proporcionar una base coherente de referencia para los participantes, así como para los lectores.

Resumen de resultados

Los participantes del Pellston WorkshopTM acordaron recomendaciones tangibles y prácticas sobre los indicadores ambientales, incluyendo innovaciones sustanciales. Las siguientes son las principales recomendaciones acordadas.

Marco de la Evaluación de Impactos del Ciclo de Vida (EICV): El marco general de EICV fue revisado distinguiéndose entre valores intrínsecos, instrumentales y culturales, así como las categorías correspondientes a daño a la salud humana y a la calidad del ecosistema (valores intrínsecos), activos socio-económicos, recursos naturales y servicios ambientales (instrumentales), y patrimonio cultural y natural (culturales).

Indicadores de daño: Los indicadores de evaluación del daño en salud humana recomendados son los años de vida perdidos por enfermedad o muerte prematura (también conocidos como años de vida ajustados por discapacidad, AVAD o DALY en inglés). En el caso de evaluación de daño en la calidad del ecosistema se recomienda utilizar la pérdida de biodiversidad, incluyendo medidas de la vulnerabilidad . Por el momento no hay indicador de daño recomendado para la pérdida de los recursos naturales y servicios del ecosistema.

Impactos del cambio climático: Se recomienda el uso de dos indicadores para la categoría de impacto del cambio climático, uno en representación de los impactos a escala de décadas (corto plazo) y otra para los impactos a escala del siglo (largo plazo). Las métricas del 5o informe de evaluación del IPCC a utilizar son el Potencial de Calentamiento Global de 100 años (GWP 100) y el cambio de temperatura potencial global de 100 años (GTP 100), respectivamente. Se recomienda utilizar dichas métricas incluyendo procesos de retroalimentación clima-ciclo del carbono para todos los Gases de Efecto Invernadero (GEI) (por el momento sólo se incluyen para el CO2). También se recomienda considerar los impactos del cambio climático de GEI de corto plazo, incluyendo gases de efecto invernadero de corta duración en los análisis de sensibilidad, donde GWP20 también puede ser utilizado como una unidad de medida alternativa para los impactos a corto plazo.

Impactos sobre la salud causados por micropartículas: Se recomiendan FC para PM2,5 primarias y se sugiere una recomendación provisional para $PM_{2.5}$ secundarias. Dichos FC distinguen entre arquetipos para zonas rurales y para zonas urbanas, así como para las emisiones y exposición en interior y en exteriores. Los FC al aire libre distinguen además entre diferentes alturas de emisión.

Impactos del uso de agua: Se discutieron y desarrollaron dos categorías de impacto. Por un lado se proporcionan FC recomendados para evaluar DALYs a nivel de daño por desnutrición, causada por la falta de agua para la irrigación de los cultivos. Por otro se sugieren FC de escasez hídrica para abordar los impactos potenciales genéricos del consumo de agua, cubriendo tanto daño potencial a ecosistemas como de privación humana. La resolución geotemporal de ambos métodos es de cuenca hidrográfica y mensual, pero para asegurar la viabilidad en caso de información de segundo plano, se proporcionan también FC agregados a nivel anual, nacional y mundial.

Impactos del uso del suelo: Se recomiendan provisionalmente FC que representan la pérdida potencial global de especies debida al uso del suelo; estos FC son adecuados para evaluar los impactos sobre la biodiversidad debido a la utilización del suelo y el cambio del uso del suelo en el análisis de puntos conflictivos en ACV (no resultando adecuados para las aseveraciones comparativas ni el etiquetado ecológico). La recomendación completa se podrá realizar a partir de más estudios con los FC, así como el desarrollo de FC para otros tipos de uso del suelo.

Temas transversales adicionales: se formularon varias recomendaciones y sugerencias sobre los temas de informes transparentes, estados de referencia, diferenciación espacial, incertidumbre, horizontes temporales, así como la manipulación de CF negativos.

Outlook y hoja de ruta

Los indicadores ambientales recomendados no deben ser considerados como algo estático sino de carácter evolutivo, representando el mejor conocimiento y práctica actual disponibles. Se recomienda encarecidamente que la UNEP/SETAC Life Cycle Initiative aproveche el impulso de cooperación y establezca una comunidad de investigadores EICV que cuiden de la gestión de los indicadores recomendados. Dicha comunidad va a expandirse con el inicio de la búsqueda de consenso para el segundo conjunto de indicadores de impacto ambiental: acidificación y eutrofización, toxicidad humana y eco-toxicidad, agotamiento de recursos minerales y servicios de los ecosistemas. Los indicadores con una clara diferenciación regional como por ejemplo los de uso del suelo y el uso del agua requieren de enfoques que equilibren complejidad y practicidad, enfoques que pueden verse beneficiados de los conocimientos adquiridos en estudios previos de ACV en los que se aplica una alta resolución geográfica. Por último, los Objetivos de Desarrollo Sostenible de las Naciones Unidas y los conceptos de límites planetarios pueden beneficiarse del trabajo realizado en este proyecto. Los indicadores ambientales recomendados pueden ser utilizados para cuantificar y controlar el progreso hacia la producción y el consumo sostenibles.

执行摘要

背景

在2030可持续发展议程中，减少人类系统在消费和生产过程所产生的环境压力是其中的一项工作重点。这项工作需要在开发产品和服务的过程中，减少对人类健康和环境的影响。建立生命周期评价指标有利于定量评估和监控人类活动对于气候变化、生物多样性、水资源等方面的影响。因此针对这些指标，我们需要建立相关的指南。

方法

为了达成环境影响评价指标的共识，the UNEP/SETAC Life Cycle Initiative（联合国环境规划署与环境毒理与化学协会所建立的生命周期倡议计划）在2013年开展了一项针对四项环境问题的全球研讨过程。这个过程基于环境影响评价指标的环境影响、政策相关性、现有定量指标的成熟度、以及达成共识的可能性进行了研讨和总结。这项工作的目的是针对生命周期环境影响评价过程中，所涉及的环境指标和特征化因子达成共识并推荐统一的标准。目前，该项目涵盖了以下五个方面的指标：1）全球变暖；2）微小颗粒物对人类健康的影响；3）水资源的使用影响（包括水资源稀缺性和对人类健康的影响）；4）土地利用对生物多样性的影响；5）环境影响评价的整体框架和跨领域问题。

不同的国际工作组用了2年多时间在这几项问题领域上进行了充分的研究，与此同时，项目在全世界范围内召集了利益相关者开展了研讨会，对研究的进展和成果进行了充分的评估。针对每一个问题领域，工作组整合以前所发表过的信息生成一个知识库，并且准备了一份白皮书，为2016年一月在西班牙瓦伦西亚所举行的专家研讨会（Pellston workshop™）作准备。为了确保这项指南的有效性，这次专家研讨会针对专家的区域代表性和专家在生命周期评价领域的建树进行了谨慎的筛选。在最终的专家名单中，我们邀请了五个问题领域的相关专家、生命周期影响评价方法的开发人员、生命周期思想研究（主要为专业顾问和工业协会）、以及生命周期信息的使用者（包括政府组织和政府间组织、政府、工业界、非政府组织和学术界）。

这个研讨会的重点是发展和统一每个问题领域中相应的环境影响指标。所有的讨论都试图在科学的严谨性和实际应用性中寻找到一个平衡，这可以确保环境指标能容易地被没有相关专业背景的人员使用。我们在建立指标的过程中，充分考虑到（相关领域专家以及指标开发人员所要求）科学复杂性和用户需要简单的、有意义的、经过反复测试和验证的环境指标，并在两者之间建立平衡。这个过程中，专家们谨慎地界定指标的目标和使用边界。为了增强理解，研讨会一项重要的内容是针对专家和本报告的读者，建立了一套可以用于文献连贯引用的术语定义表。

成果总结

Pellston Workshop™专家研讨会的成员针对环境影响评价指标，达成了有效和实用的建议，并且在这个过程中实现了很大的创新。以下列出专家达成共识的主要建议：

生命周期影响评价框架：整体的框架进行了微小的修改之后，目前能够区别内在的、功能性的、文化价值、损害类型指标（人类健康和内在的生态系统质量）、社会经济价值、自然资源和生态系统服务功能以及文化和自然遗产。

损害类型指标：本报告推荐的损害类型指标包括伤残调整寿命年（DALY，人类健康）和生物多样性损失（包括衡量生态系统质量的脆弱性）。对于自然资源和生态系统服务，目前还没有推荐的损害类型指标。

气候变化影响：本报告推荐使用两项气候影响类别。一项代表十年尺度（短期）和一项代表百

年尺度（长期）的影响。政府间气候变化专门委员会的《第五次评估报告》分别推荐了使用百年全球变暖潜能值(GWP 100)和百年全球温度变化潜能值（GTP 100）。本报告推荐使用包括针对所有气候强迫因子 （目前仅包括二氧化碳 ）的气候一碳循环响应衡量标准。本报告也同时推荐涉及近期气候强迫因子（包括对短寿命温室气体的敏感度分析）对气候变化的影响，在这种情况下，GWP20可以做为短期影响评价的替代指标。

细颗粒物对健康的影响：建立了推荐的针对一级$PM_{2.5}$，和临时推荐的特征化因子二级$PM_{2.5}$的 特征化因子。这些特征化因子区别对待城市和郊区地区、室内和室外排放、以及暴露设置的模型。与此同时，室外特征化因子区别可以不同的烟囱排放高度。

水资源利用影响：讨论和开发了两个影响类别，最终推荐了由营养不良导致的DALYS特征化因子，这些影响是由于缺少水资源对食物生产灌溉以及针对水资源消耗（水资源的稀缺性对生态环境和人类的影响）所产生的。两种方法的精确度针对每月的流域数据，但从背景环境清单的可操作性出发，推荐的特征化因子在年度、国家、和全球层面进行了汇总。

土地利用影响：本报告推荐了代表由土地利用所导致的全球潜在物种减少的特征化因子，这个特征化因子仅针对于生命周期评价的热点分析，做为临时特征化因子评估土地利用和土地利用变化对生物多样性影响所推荐使用。为了推荐全面的指标，未来需要针对土地利用类型的特征化因子进行深度的测试和开发。

额外的跨领域交叉问题：针对报告的透明度、基准状态、空间差异、不确定性、时间跨度、以及处理特征化因子的负值，本报告提供了一些相关的建议和指导。

展望与实施路线

本报告所推荐的环境指标并不是静态的，他们是革命性的并且代表了当前最前沿的知识和实践经验。我们强烈建议生命周期倡议计划利用本次合作的契机，为从事生命周期环境影响评价的学者们创立一个合作平台。这个平台在今后推荐使用相关的生命周期环境影响评价指标中能够不断完善，并且在第二阶段推荐其他的指标（酸化和富营养化、人类毒性和生态毒性、矿产资源消耗、生态系统服务）。在空间上有区别的指标（比如土地利用和水资源利用）需要更加智能和简便的方法，这些方法可以从一些具有高地理解析度的生命周期评价项目中获取经验。最终，联合国可持续发展目标和地球边界理念可以从个项目中受益。这个报告中所推荐的环境指标可用于定量分析并监控可持续生产和消费的进度。

7. Integration and synthesis

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7.1 The SETAC Pellston Workshop® process

This guidance document is a result of intensive efforts by an international group of experts to identify consensus on selected environmental impact category indicators, on the overall life cycle impact assessment framework, and on crosscutting issues. A careful evaluation of existing environmental impact category indicators representing climate change impacts, human health impacts caused by particulate matter, water scarcity, and human health impacts due to water use, as well as biodiversity impacts related to land use was brought to a focused analysis process. Findings and recommendations on these indicators, on the overall framework, and on crosscutting issues are presented in the previous chapters. These recommendations show a variable level of maturity and degree of reliance and confidence, which need to be taken into account when applying the recommended indicators.

The topics addressed are not stand-alone, but have the potential of being integrated into the bigger picture of life cycle impact assessment. This chapter provides such an integration and synthesis, as well as key messages of the topics covered. One element of this integration encompasses the overall framework and crosscutting issues to which all recommended environmental impact category indicators refer. Developing further environmental impact category indicators systematically in line with the overall framework and adhering to the recommendations related to crosscutting issues is highly important and strongly recommended by the guidance principles. This will foster the application and the acceptance of life cycle-based environmental indicators and facilitate the development of comprehensive and consistent life cycle impact assessment (LCIA) methods.

7.2 Overall framework and crosscutting issues

Currently there are a number of crosscutting issues that need harmonization, either across all impact categories and damage categories (previously named areas of protection, Jolliet et al. 2004, #2608) or within a specific damage category, such as standardization of spatial resolution or of its description, harmonized endpoint indicators, and normalization procedures.

The main novelties emerging from the workshop are:

- an updated LCIA framework distinguishing intrinsic, instrumental, and cultural values to encompass six damage categories (human health, ecosystem quality, cultural heritage, natural heritage, socio-economic assets, as well as natural resources and ecosystem services)
- guidance to improve consistency of the approach across reference states, spatial differentiation, and time frames

A number of recommendations are listed in Chapter 2 for method developers and practitioners. For the former, the following is highlighted:

- We strongly recommend documentation is made more transparent, especially regarding the impact pathway, units, reference states, uncertainties, spatial scale, modeling and data choices, and the rationale for those.
- We strongly recommend that the spatial scale of regionalized models reflects the nature of impact, that CFs are reported at the original and aggregated scale, both with information on uncertainty and variability.
- We recommend that, if possible, quantitative uncertainty is reported for CFs; otherwise, qualitative descriptions of uncertainty should be provided
- We recommend that CFs for two different time horizons (till 100 years and long-term), are provided whenever relevant, and in a way that makes them additive
- We recommend that consistent global normalization references are provided
- We recommend the characterization of ecosystems and/or species in a way that takes resilience, rarity, and recoverability into account
- We advise that marginal and average characterization factors are provided, which are, respectively, more suitable for studies of small and large systems
- We advise that the reference state is consistent across impact categories

Additionally, we recommend that practitioners use global normalization values and report transparently the selected normalization and (if applicable) weighting approaches, and the rationale behind these choices.

Not all the discussed points, however, were suitable for final recommendations. This is mainly because the knowledge on these topics is not yet sufficiently developed and/or the understanding on the approaches proposed is yet limited. Thus, future research is required, in particular on the following topics:

- Investigating and agreeing upon a framework for uncertainty assessment of impact assessment methods and improving the quantitative uncertainty assessment
- Including and developing methods to assess instrumental damages to socio-economic assets, ecosystem services, and resources
- Strengthening current biodiversity impact approaches through inclusion of vulnerability
- Developing approaches for weighting of CFs at different ecosystem scales or different taxa
- Investigating options to operationalize methods dealing with ecosystem services
- Coordinating with life cycle inventory and LCA software developers to ensure inclusion of uncertainty assessments
- Testing methods that provide both marginal and average effect factors with case study applications
- Developing consistent sets of global normalization values and references

7.3 Greenhouse gas emissions and climate change impacts

Global warming potential (GWP) with a time horizon (TH) of 100 years is the most widely quoted metric in all LCIA methods when quantifying climate change impacts from emissions of greenhouse gases (GHGs). With the recent advances in climate science, it has become evident that while still relevant, GWP100 is only one of the possible metrics. Other metrics can provide complementary information to decision makers about the climate change impacts of a product or system. Some GHGs, also referred to as well-mixed GHGs (WMGHGs), have lifetimes that last years to millennia. They contribute to the rate of change and to the long term increase in global temperature. Near term climate forcers (NTCFs), like ozone precursors and aerosols, have lifetimes from a few days to a few months. At present, there is no single indicator that can adequately inform about the climate impact dynamics from such a variety of forcing agents and lifetimes. The task force on global warming reviewed the recently proposed metrics in the IPCC fifth assessment report (IPCC AR5) and came to the conclusion that it makes sense to use several complementary metrics that serve different purposes to understand how LCA results are sensitive to different modeling choices. Workshop participants arrived at the recommendation to use two impact categories, one for shorter-term impacts (based on GWP100), targeting contributions to the rate of warming, and the second for long term temperature changes (based on global temperature change potentials, GTP100).

The proposed units for GWP100 and GTP100 are kg CO_2e (short) and kg CO_2e (long), respectively. Their values are not to be combined to generate a total impact, as they represent different impacts. When calculating these metrics, climate-carbon cycle feedbacks for both non-CO_2 GHGs and CO_2 have to be considered for more consistency, as recommended in IPCC AR5. Contributions from NTCFs have been usually excluded in LCA, despite their potential significant impacts on the climate system. The latest IPCC assessment report summarized emission metrics for NTCFs as well, which are affected by larger uncertainty ranges than metrics for WMGHGs. For NTCFs, it is thus recommended to perform sensitivity analyses using the range of values summarized in Chapter 3, including GWP20 as alternative characterization factors for shorter term impacts.

7.4 Health impacts of fine particulate matter

To date, health impacts of particulate matter (PM) and specifically the respirable fraction of PM less than 2.5 microns in mass median diameter, termed $PM_{2.5}$, have not been consistently incorporated in LCIA modeling. One of the major goals of the PM task force was to rectify this situation using the latest science and fate and effects modeling, and to ensure the results of the LCIA modeling was consistent with the epidemiologic literature for relevant indoor and outdoor environments. The primary reference data source driving this effort is the Global Burden of Disease last updated and published in 2015.

The task force effort resulted in a number of innovations that brought an LCIA approach to address health impacts from exposure to $PM_{2.5}$. In a kick-off experts workshop several issues were identified and evaluated by the task force members and then organized by priority, relevance, and feasibility. Among the task force innovations are specific recommendations to address a variable range of source-to-exposure archetypes and the ability to treat secondary $PM_{2.5}$ (formed in the atmosphere from gaseous precursors), as well as primary $PM_{2.5}$.

Although the most fundamental form of the $PM_{2.5}$ model conforms exactly to the decades old standard of IMPACT = EMISSION X CF, the elaboration of this model within the archetypes and within an LCA framework required numerous innovations in both the source-to-exposure component (population intake per kg emitted) and in the exposure-to-impact endpoint assessment, with impact expressed in cumulative disability-adjusted life years (DALYs) per kg intake.

In developing a framework for addressing PM2.5 in LCIA, the task force made a number of overarching and specific recommendations. Many of these recommendations deal with actions that increase both the reliability of and confidence in modeling exposure and applying exposure-response functions (ERFs) in the context of available data. The task force found that modeling results closely matched monitoring data in several situations, thus lending confidence to the actions proposed. The task force's main recommendations address both the process for linking emissions to exposure and the process for linking exposure to disease and mortality. Summarized and prioritized below are overarching recommendations.

Strong Recommendations:

- Use the intake fraction to capture source-receptor relationships for both primary and secondary $PM_{2.5}$ for both outdoor and indoor emissions.
- Organize impacts and exposures organized according to whether emissions originate outdoors or indoors, in urban or rural regions, and as ground-level versus stack emissions. Where possible use city-specific intake fractions to capture large intra-urban variability.
- Make use of available and well-vetted exposure-response models for assessing both total mortality and disease-specific DALYs associated with $PM_{2.5}$ exposures both indoors and outdoors.
- Include background exposure to $PM_{2.5}$, as well as background disease incidence (and/or mortality) in the calculation of impacts for any selected population to ensure proper application of these models to LCIA.

Recommendations:

- Make use of interim recommended generic factors for very high, high, and low stack emissions based on the use of ground level emissions and correction factors from current literature until better models become available.
- Make use of current literature values for secondary $PM_{2.5}$ formation indoors.
- Include qualitative and (when possible) quantitative characterization of variability and uncertainty.

Interim Recommendations:

- Make use of global exposure distributions to characterize the impacts of emissions when emission locations are not specified and in the absence of more detailed data or information.
- Use high-background indoor $PM_{2.5}$ values associated with solid fuel cooking in regions where these data are available.
- Focus on primary $PM_{2.5}$ impacts in urban areas when detailed models of secondary $PM_{2.5}$ formation are not available.

7.5 Water use related impacts: water scarcity and human health effects

7.5.1 Water scarcity

According to the ISO water footprint standard, water scarcity is the "extent to which demand for water compares to the replenishment of water in an area, such as a drainage basin." While most existing water scarcity indicators were defined to be applicable either for human health or ecosystems impacts, we developed a generic water scarcity indicator. However, in addition to this scarcity aspect, the group designed an indicator that allows for absolute availability to be reflected as well, based on the outcome of a two-year consensus building activity by the water use in life cycle assessment (WULCA) working group. The CF aims to answer the question, "What is the potential to deprive another user (human or ecosystem) when consuming water in this area?" It is calculated on watershed level (~11'000 units) and on a monthly level with global coverage.

Based on the evaluation of different methods we recommend the use of the "AWARE" approach, which is based on the quantification of the relative Available WAter REmaining per area once the demand of humans and aquatic ecosystems has been met. In other words, the method quantifies a surface-time equivalent that would be required to replenish the water consumed without depriving other users. In areas where current demand already exceeds availability in a watershed and a specific month, a cut-off value is required. This value is set at 100 times the global average value on the upper hand and also limited to 0.1 of global average situation at the lower end, in order to limit the span. Due to the conceptual difference with previously existing scarcity indicators, we strongly recommend performing a sensitivity analysis with a conceptually different method to test the robustness of the results, keeping in mind that different results are sometimes to be expected.

In terms of choice of spatial and temporal scale, we strongly recommend applying CF at monthly and WS scale if possible. If for practical reasons (e.g., background data) this is not possible, we strongly recommend to use sector-specific aggregation of CF on country and/or annual level (differentiated for agricultural and non-agricultural use). Our least recommended approach is to apply generic CFs on country-annual level. Global CFs are provided but not recommended for use.

Additionally, it is important to provide non-marginal characterization factors that will be applied to bigger changes and footprint studies. To better assess crop production, which dominates global water consumption, we suggest that CFs aggregated on year and annual level could be calculated to represent crop-specific patterns based on growing seasons and watersheds. This would allow higher precision when assessing crops with crop-specific aggregation of CFs, when month and watershed is unknown.

Any aggregation shall include uncertainty information induced by the underlying variability.

7.5.2 Human Health effects

Domestic and agricultural water scarcity has been recognized as a relevant pathway in which water consumption may lead to damage of human health. While water deprivation for domestic use may increase the risks of intake of low quality water or lack of water for hygienic purposes, water demand in agriculture (irrigation) and fisheries or aquaculture are necessary for human nutrition in many areas of the world. In this context, deficit of water in agriculture and fisheries or aquaculture may decrease food production, and consequently result in the increase of malnutrition damage due to the shortage of food supply.

Human health characterization factors specifying DALY lost from reduced food production have been modeled based on existing publications. In addition to these methods, the human health endpoint CF includes inequality adjusted adaptation capacity on country level to better reflect exposure of a population to food deficit. The trade model has been improved, including the consideration of stock of food in each country. Moreover, the "fate" factor based on scarcity has been aligned to consider a similar reasoning as the AWARE recommendation, i.e., including available water remaining for human uses.

The characterization factors for human health are recommended for use. High uncertainties in the modeling are highlighted and should be assessed in LCIA. The CFs are provided on watershed and monthly level and it is strongly recommended to apply them at this level of resolution. For practical applications, temporal and geographical resolution of inventory might be missing, therefore country and global average values are provided, including uncertainty induced by variability within countries and months. Global CFs are provided but not recommended for use. The characterization factors provided together with this publication are recommended for marginal applications only.

The effects of water use on human health quantified with the recommended indicator are based on a series of potentially valid but yet unproven assumptions, based on previous published literature. In future research, additional refinement of the modeling of the adaptation capacity (e.g., sub-regional maps of GDP (PPP) per capita) should be investigated to increase robustness of the malnutrition vulnerability (relating DALY to lack of food supply), as well as for improving the trade effect. The trade effect model should be enhanced in future research to better account for price elasticity and its effects on nutrition. Further investigation about the robustness of the use of calories deficit relation to protein-calories malnutrition is required and more specific data on regional health responses to malnutrition should be investigated.

Since no CF are ready for suggestion to be used, additional analyses are required for the assessment of the cause-effect relationship between domestic water scarcity and damage associated to lack of water for sanitation (i.e., water-related diseases). In particular, the question to what extent these effects are triggered by an additional water use in an area should be further investigated.

Finally, water quality aspects or source of water availabilities (e.g., ground or surface water) need to be assessed once global data of satisfying quality becomes available.

7.6 Land use related impacts on biodiversity

Building on the important methodological developments that have taken place in the last few years, this workshop provides a significant breakthrough in the recommendation of a model and indicator allowing the consistent consideration of potential species loss from land use in LCA. Enabling the routine and consistent consideration of land use impacts on biodiversity among the impact areas commonly considered in LCA is thus the main contribution of the consensus built among the experts in the workshop. Additionally, the value and robustness of the method suggested also merits highlighting. Indeed, the indicator recommended by the authors addresses a significant share of the aspects considered as important by stakeholders in the assessment of biodiversity impacts. Namely, the model builds on species richness; incorporates the local effect of different land uses on biodiversity; links land use to species loss; includes the relative scarcity of affected ecosystems; and includes the threat level of species.

On the other hand, the limitations of the model in addressing the inherent complexity of biodiversity have also been highlighted, in particular the limited number of taxa covered (vascular plants, mammals, birds, amphibians, reptiles); the exclusion of attributes of genetic or ecosystem diversity and of processes such as fragmentation; and the deficient capture of effects of main land management practices on biodiversity.

As an interim recommendation we propose the global average characterization factors (CFs) quantifying potential species loss (PSL) from land use and land use change and suitable for hotspot analysis in LCA. We strongly recommend against using these CFs for comparative assertions. When used internally in a company for product comparisons we recommend against using it in isolation without further assessment of the specific biodiversity risks and potential management options.

The CFs provided are applicable in hotspots analysis from LCA, thus guiding in the identification of regions and processes requiring special attention due to their potential impact on biodiversity. The users are guided on the interpretation when such hotspots are identified, and the follow-up assessments required. Even though the implementation of the CFs provided will require some mapping effort by the practitioners (and eventually by LCA database managers) of the land use flows used in the recommended method to those specified in the main life cycle inventory nomenclatures, the model is deemed applicable for practical use in current LCA software and practice.

Some immediate developments are required to upgrade the interim recommendation to full recommendation of CFs. These improvements comprise the refinement of land use classes considered including different management regimes, the inclusion of additional taxa, the development of best practice information for use, and interpretation of the impact assessment results, as well as testing of CFs in sufficient case studies to explore the robustness and ability of the model to identify potential biodiversity impacts.

7.7 Achievements, vision and roadmap(s)

The work and discussions before and during the Pellston workshop resulted in relevant recommendations in the four topical areas climate change, particulate matter, water use impacts, and land use impacts, as well as with regard to the LCIA framework and cross-cutting issues. The characterization factors and impact category indicators recommended include latest findings of topical research and clearly go beyond current practice. The levels of recommendation show the variable maturity of the indicators (see Table 1). At the same time, care has been taken to ensure immediate applicability in current LCA environments.

Hence, this workshop format turned out to promote progress in science and at the same time foster the practicality and robustness of the recommended indicators.

Given the dynamics in this research area, the recommended characterization factors should not be seen as given and static, but rather evolutionary. Expected and welcome changes will further improve the robustness, topical coverage, and applicability of the environmental impact indicators recommended today.

The Pellston workshop successfully proved the willingness of co-operation in the field of LCIA research and development. The task forces should maintain and increase the momentum achieved through this effort. The Life Cycle Initiative should take care of the stewardship of the recommended indicators and characterization factors. The Life Cycle Initiative should help build a structure for a community of LCIA research teams and organizations to maintain the consensus indicators and characterization factors. This community may start with the task forces dealing with the topics discussed during this Pellston Workshop. The community should take care of capacity building and establish recommendations on the proper use and interpretation of the environmental indicators they developed. The community may grow when launching consensus finding processes for additional environmental impact indicators such as acidification & eutrophication, human toxicity, and mineral resource depletion.

Spatial resolution is an issue common to three out of the four topical areas, i.e., particulate matter emissions, water use impacts, and land use impacts. All three groups agreed on providing characterization factors on the native scale (like watersheds or ecoregions), as well as on more aggregated levels such as countries, continents, and the globe (water use impacts and land use impacts), or archetypes such as indoor or outdoor and rural or urban (PM).

While the need for spatial differentiation is acknowledged in decision situations dealing with the foreground system, it is a challenge to underpin spatially explicit product LCA models with the LCI data and information required. Thus, it is an important task to derive smart and parsimonious approaches from the knowledge gained in LCA research projects in which a high geographic resolution is applied.

The United Nations Sustainable Development Goals (United Nations 2015) cover topics such as climate action (goal 13), clean water and sanitation (goal 6), life on land (goal 15), and good health and wellbeing (goal 3). It will be a promising and important challenge to explore the possibilities of using the environmental indicators recommended in this report in supporting actions to improve the environmental situation and to monitor progress relative to selected sustainable development goals. Similarly, we strongly recommend exploring options and opportunities on how to make use of the environmental indicators when quantifying environmental planetary boundaries.

7.8 References

United Nations. 2015.
United Nations (2015) Resolution adopted by the General Assembly on 25 September 2015: Transforming our world: the 2030 Agenda for Sustainable Development. United Nations General Assembly, New York, USA.

Table 7.1: Characteristics of the environmental life cycle impact category indicators recommended, their domain of applicability and the level of recommendation

Impact category and subcategory	Cause-effect description	Indicator retained - Position in the cause effect chain Metric Unit	Factors of influence - Considered, spatial resolution Archetypes Time horizon	Domain of applicability	Level of recom-mendation
Climate change impacts					
Shorter-term climate change (rate of climate change, impacts related to the adaptation capacity of humans and ecosystems)	Cumulative radiative forcing	Global warming potential (GWP) kg CO_2e (short)	Global 100 years	No restrictions	Strongly recom-mended
Long–term climate change (long-term temperature increase and related impacts on ecosystems and humans)	Instantaneous temperature	Global temperature change potential (GTP) kg CO_2e (long)	Global 100 years	No restrictions	Strongly recom-mended
Particulate matter impacts					
Health effects caused by primary and secondary fine particulate matter	All-cause mortality	Number of deaths per kg emitted	Indoor/outdoor Urban/rural Ground level, low/high/ very high stack	Global, using archetypes as described left	Strongly recom-mended, interim
Water use impacts					
Scarcity	Surface-time equivalent required to generate one cubic meter of unused water	Surface time equivalents (STE) m^3 world eq./m^3i	Native scales: Geographic: Watersheds Temporal: Month Use: Agricultural/industrial Integration to regions, countries, continents and global	Global, marginal impacts generated by < 5 % of total water consumption in a given area	Recom-mended
Health effects	Impacts caused by malnutrition	Change in water availability to agricultural production due to water consumption	Native scales: Geographic: Watersheds Temporal: Year Integration to regions, countries, continents and global	Special attention recommended to the interpretation of food-producing systems	Recom-mended
Land use impacts on biodiversity					
Potential species loss	Effect of land occupation displacing entirely or reducing the species which would otherwise exist on that land	Indicator accounts for the relative abundance of species and their overall global threat level	5 taxa (birds, mammals, reptiles, amphibians and vascular plants) Geographic: 800+ ecoregions Reference state: Natural habitat	Hot spot analyses, Not to be used in comparative assertions disclosed to the public	Recom-mended, interim

About the Life Cycle Initiative

The Global Life Cycle Initiative was established by UNEP and SETAC. Among other things, the Life Cycle Initiative builds upon and provides support to the on-going work of UNEP on sustainable consumption and production, such as industry outreach, industrial pollution management, sustainable consumption, cleaner and safer production, Global Reporting Initiative (GRI), Global Compact, UN Consumer Guidelines, tourism, advertising, eco-design, and product service systems.

The Initiative's efforts are complemented by SETAC's international infrastructure and its publishing efforts in support of the LCA community.

The Life Cycle Initiative is a response to the call from governments for a life cycle economy in the Malmö Declaration (2000). It contributes to the 10-year framework of programmes to promote sustainable consumption and production patterns, as requested at the World Summit on Sustainable Development (WSSD) in Johannesburg (2002).

The Life Cycle Initiative's vision is a world where life cycle approaches are mainstreamed and its mission is to enable the global use of credible life cycle knowledge for more sustainable societies.

Our current work is building on the Life Cycle Initiative's continual strength to maintain and enhance life cycle assessment and management methodologies and build capacity globally. As we look to the future, life cycle assessment (LCA) and life cycle management (LCM) knowledge is the Life Cycle Initiative's anchor, but we will advance activities on LCA and LCM to make a difference within the real world.

Therefore, the renewed objectives are the following:

Objective 1: Enhance the global consensus and relevance of existing and emerging life cycle methodologies and data management

Objective 2: Expand capability worldwide to apply and to improve life cycle approaches; making them operational for organizations

Objective 3: Communicate current life cycle knowledge and be the global voice of the life cycle community to influence and partner with stakeholders

For more information,
www.lifecycleinitiative.org

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About SETAC

The Society of Environmental Toxicology and Chemistry (SETAC) is a professional society in the form of a not-for-profit association, established to promote the use of a multidisciplinary approach to solving problems of the impact of chemicals and technology on the environment. Environmental problems often require a combination of expertise from chemistry, toxicology, and a range of other disciplines to develop effective solutions. SETAC provides a neutral meeting ground for scientists working in universities, governments, and industry who meet, as private persons not bound to defend positions, but simply to use the best science available.

Among other things, SETAC has taken a leading role in the development of life cycle management (LCM) and life cycle assessment (LCA).

The organization is often quoted as a reference on LCA matters.

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About the UNEP Division of Technology, Industry and Economics (DTIE)

Set up in 1975, three years after UNEP, the Division of Technology, Industry and Economics (DTIE) provides solutions to decision makers and helps change the business environment by offering platforms for multi-stakeholder dialogue and cooperation, innovative policy options, pilot projects, and creative market mechanisms to improve the quality of the environment and the well-being of citizens.

Within UNEP, DTIE has the mandate of delivering on environmental sustainability through technology, industry, and economic policy by addressing environmental issues at global and regional levels, providing leadership and encouraging partnerships, and by informing and enabling nations and people to improve their quality of life without compromising that of future generations.

DTIE plays a leading role in three of UNEP's seven strategic priorities, namely in climate change, chemicals and waste, and resource efficiency.

The Office of the Director, located in Paris, coordinates activities through:

- The **Chemicals and Waste Branch** (Geneva, Paris and Osaka), which catalyzes global actions to bring about the sound management of chemicals, the improvement of chemical safety and the management of waste.
- **The International Environmental Technology Centre - IETC** (Osaka) promotes the collection and dissemination of knowledge on environmentally sound technologies with a focus on waste management. The broad objective is to enhance the understanding of converting waste into a resource and thus reduce impacts on human health and the environment (land, water, and air).
- **OzonAction** (Paris) supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- The **Economy and Trade Branch** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies. This branch is also charged with producing green economy reports.
- The **Energy, Climate, and Technology Branch** (Paris, Nairobi, and Copenhagen), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- The **Sustainable Lifestyles, Cities and Industry Branch** (Paris), which delivers support to the shift to sustainable consumption and production patterns as a core contribution to sustainable development.

DTIE works with many partners (other UN agencies and programmes, international organizations, governments, non-governmental organizations, business, industry, the media, and the public) to raise awareness, improve the transfer of knowledge and information, foster technological cooperation, and implement international conventions and agreements.

For more information,

www.unep.org/dtie

Which quantitative and life cycle-based indicators are best suited to quantify and monitor man-made impacts on climate change, biodiversity, water resources, and other aspects of the biophysical environment?

The Global Guidance for Life Cycle Impact Assessment Indicators (Volume 1) goes some way to address this question by identifying the "current best available practice" in a variety of areas: climate change, human health impacts of fine particulate matter, water use impacts, and land-use impacts on biodiversity. The global importance of these impact areas is also recognized in specific Sustainable Development Goals (SDGs).

This guidance document contains a reservoir of useful and practical information that reflects the dedicated effort and collaboration of many scientists, engineers, and LCA practitioners from around the globe. Aimed at life cycle assessment practitioners and method developers, it enhances the comprehensive and consistent assessment of impacts in production and consumption systems throughout their life cycle, making explicit any potential trade-offs and supporting more sustainable processes. It provides a significant leap forward in the environmental representation and accuracy of the internationally endorsed, scientifically robust, and stable indicators while enhancing comparability among LCA studies.

This guidance document should be on the physical and electronic desktops of practitioners as well as those that will benefit from and make use of the outputs of LCA.

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