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## 29. LCSA in the regions – state of the art, mainstreaming conditions and upscaling approaches

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### INTRODUCTION

Decision-makers increasingly require sustainability from businesses, local governments, and funding sectors. Some sustainability approaches, such as ESG (Environment, Social, and Governance), are gaining momentum, but lack a globally recognized and standardized methodology. Life Cycle Sustainability Assessment (LCSA) emerges as a promising framework that, however, carries over some limitations from life cycle assessment (LCA) developments, particularly limited data availability and the lack of LCSA applications and capacities in multiple regions of the world. In the context of this chapter, regions are understood as societies in emerging and developing economies worldwide.

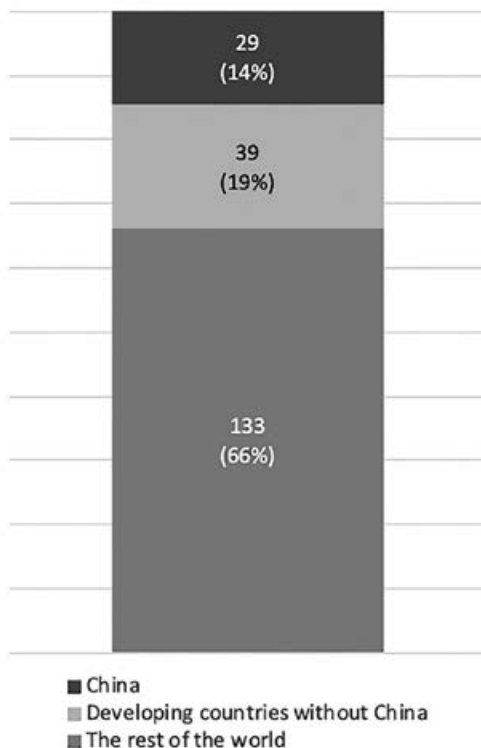
This chapter aims to provide a state of the art of the implementation of LCSA in the world with a special focus on developing countries, analyzing published LCSA studies based on Leroy-Parmentier et al. (2023), who reviewed 193 studies and on our own research by adding eight recent studies identified. This resulted in 201 papers being considered for the review in total. As part of the state of the art, the situation of LCA networks in the regions and access to local data are considered.

The main goal of the chapter is to analyze the conditions in the regions for mainstreaming LCSA practice. This is done using the criteria developed by Valdivia et al. (2015) for assessing mainstreaming conditions for implementing environmental LCA. The final objective of this chapter is to identify promising approaches for upscaling LCSA practice and potential key multipliers for spreading the LCSA methodology, as well as target audiences for LCSA in the regions based on the results of the analysis done before. The chapter closes with a conclusion section summarizing the key findings.

### STATE OF THE ART

If looking at the global distribution of LCSA studies in the world, as done in Figure 29.1, the share is much less for papers from non-industrialized countries (about 34% or 68 studies out of 201). Regarding publications from developing countries without China, it is worth noting that only 39 out of 201 (19%) papers are from these countries.

The following observations arising from the review of the papers can be highlighted.



Note: Total LCSA publications: 201.

Source: Authors' own work.

Figure 29.1 Global distribution of LCSA studies as of 2022

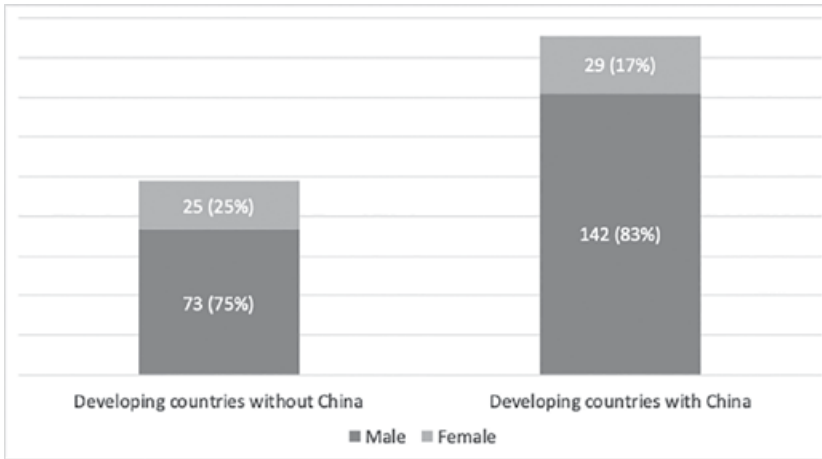
## Gender

Concerning gender, it can be noted that the 201 identified papers published worldwide up to 2022 have in total 560 named authors, out of which 150 are female (27%). Based on individual names, about 21 female authors in total have been identified. These women authors published (or co-published) between 1 and 11 papers. As shown in Figure 29.2, female authors of publications from developing countries including China make up 17% (29 out of 171) of authors in total or 25% without China (25 female authors out of 98 authors in total).

As evidenced in Figure 29.2, these indicators confirm the gender gap in the scientific arena concerning LCSA publications.

The gender gap is a relevant aspect to be assessed in line with national and international trends. According to the word map prepared by Hennig (2019) in Figure 29.3, the gender inequality index by 2019 still shows slight to severe gaps in most parts of the world.

Improving these gender gap ratios will contribute to the 2030 Agenda for Sustainable Development (UN, 2015) Sustainable Development Goal (SDG) 5, which aims to “achieve gender equality and empower all women and girls.”



Note: Total LCSA publications: 201.  
 Source: Authors' own work.

Figure 29.2 Female authorship of LCSA publications from developing countries as of 2022

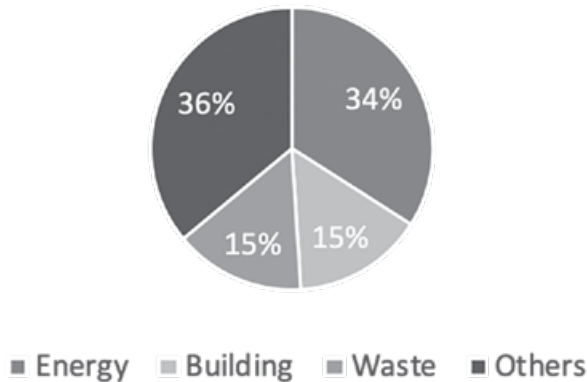


Source: Hennig (2019).

Figure 29.3 Gender inequality index (worldwide)

### Sustainability Hotspots in Developing Countries

Sustainability hotspots are inferred from the learnings on areas covered mainly by the 68 publications identified from developing countries, including China. Energy (34%), building (15%), and waste management (15%) sectors stand out in the existing LCSA papers landscape (see Figure 29.4). A highlight is the number of LCSA papers on energy published in China (11 publications). These most published themes are clearly the ones that the authors were motivated to address in an LCSA study and had the resources and data to do so.



Note: Basis: 68 papers.  
 Source: Authors' own work.

Figure 29.4 Most published themes in LCSA-related papers in developing countries

TOPIC	China	Thailand	Mauritius	Brazil	India	Vietnam	Pakistan	Cuba	Chile	Malaysia	Iran	South Africa	Mozambique	Tunisia
Energy	11	0	0	1	4	3	1	0	1	0	0	1	0	1
Chemical industry	2	1	0	0	0	0	0	0	0	0	3	0	0	0
Agricultural management	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Forestry	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mobility	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Food	0	0	0	1	0	0	0	0	0	1	0	1	0	0
Building	1	0	0	4	0	0	0	1	0	3	0	0	0	0
Manufacturing	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Logistics	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Waste management	1	3	1	2	1	0	0	0	0	0	0	0	1	0
Industrial systems	9	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Biotechnology	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chemistry	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Materials	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 29.5 Themes with at least one publication covered by developing countries

From the most published themes identified for developing countries (see also Figure 29.5), it can be inferred that these reflect sensitive areas in the countries from a community or national perspective: energy, housing, and waste management related. These priorities are different from the mostly addressed themes in industrialized countries, which deal mainly with the following issues:

- Mobility, with 13% of the papers in industrialized countries covering this theme compared to 1% in developing countries,
- Manufacturing, with 11% in industrialized countries compared to 3% in developing countries, and
- Waste management, with 4% in industrialized countries compared to 13% in developing countries.

A more detailed overview of the themes covered by developing countries with at least one publication is given in Figure 29.5. It also becomes clear that the transition of water-agriculture-food systems, as well as chemical industry and industrial systems in general (in particular in China), are emerging topics addressed through LCSA in developing countries.

Based on these findings, for expanding LCSA in the regions, a tailored approach will be crucial, one that enhances impact assessment models addressing these sectors supported with local data availability. The development of dedicated databases for facilitating the execution of LCSA studies in the regions need to be envisaged.

### Techniques Used in LCSA Studies

From the LCSA papers published from developing countries, 71% conducted an (environmental) LCA and 62% a social LCA (S-LCA), with 65% of the cases applying LCC as a technique for the economic assessment as opposed to other techniques. About 60% applied the three techniques together, fulfilling the completeness principle according to the LCSA principles published by Valdivia et al. (2021). Regarding the remaining techniques, we can see that these are mainly based on the multi-criteria decision-making (MCDM) or multi-attributes decision-making (MADM) approaches, but also on the scenario analysis often used in environmental LCA. Interestingly, some techniques used are based on sustainability indexes such as the human development index (HDI)<sup>1</sup> and the composite life cycle sustainability index,<sup>2</sup> among others, which do not follow ISO 14040/44.

### Academia vs Private Sector Publications

Out of the 201 papers published, authorship comes predominantly from academia, with only five studies developed by non-academia organizations (consultancy companies or private enterprises). In developing countries, all papers published are from academia.

This may be explained by the fact that the majority of private sector organizations are not engaged in scientific work. Another reason is priority and the resources available (e.g., time) and copyright issues (confidentiality aspects). This finding regarding lack of non-academia dissemination of LCSA-related results is attributable to all private sector organizations.

### LCSA Capacities and Life Cycle Networks

Figure 29.6, which shows the life cycle networks and/or life cycle databases in developing and BRICS countries (i.e., Brazil, Russia, India, China, and South Africa), illustrates that there is a lack of active groups forming life cycle networks in Africa, which contrasts with the Latin American region and parts of Asia. This can be explained by the long-term activity of the Iberoamerican Life Cycle Network (<https://rediberoamericanacv.net/>), which strongly



Source: Authors' own work.

Figure 29.6 Developing countries and BRICS with life cycle networks and/or life cycle databases

advocates life cycle thinking in the Latin American region and comprises all networks in this region. The life cycle networks in developing countries are included in Table 29.1.

### Local Data

Few countries, particularly developing countries, have national life cycle databases, and where such databases do exist, they concern only the environmental dimension. See in Table 29.1 the databases identified.

No local social-specific LCA data has been considered so far, either in local databases or in existing international databases such as PSILCA (Product Social Impact Life Cycle Assessment database; Maister et al., 2020) or SHDB (Social Hotspots Database; Benoit-Norris and Norris, 2015).

## MAINSTREAMING CONDITIONS

Inspired by the criteria developed by Valdivia et al. (2015) for assessing mainstreaming conditions for the implementation of environmental LCA, the following criteria are considered for understanding the mainstreaming conditions for LCSA application in the regions:

1. **LCA and S-LCA studies available.** Studies published directly result in local data availability and organizations starting to implement LCSA. The scores have the following interpretations: 0: not at all; 1: few LCA or S-LCA studies; 2: many covering LCA and some S-LCA separately; and 3: many LCA and S-LCA and some LCSA studies.
2. **Adequate LCA database and S-LCA data** for key sectors and local conditions in the regions available. This is the basic infrastructure needed to have the potential to mainstream LCSA. Three cases are considered: 0: there is no database or it is under development; 1: local LCA datasets are available for core sectors in the country; 2: local LCA database is available; and 3: local LCA database and adequate S-LCA data for local conditions are available.
3. **Active national life cycle network(s).** These networks can function as a significant multiplier for applications of LCSA by organizations. Two possible scores are considered to reflect the existence (“1”) or not (“0”) of a network in the country.

See chapters 5, 6, 7 and 8 for more on LCSA, LCA, LCC and S-LCA, respectively.

A summary of the assessment scoring of the mainstreaming conditions in countries with at least a life cycle network, life cycle database, or LCSA publications is provided in Table 29.1. For the mainstreaming conditions assessment, only those countries from which LCSA studies were published were assessed, with the exception that, where countries have no published papers yet but do have a national LCA database, these could be included in the assessment too, given the assumption that having existing studies and/or a national database are basic conditions for expanding LCSA. Results from applying the criteria vary from 0 to 6, where 4+ is interpreted as the minimum conditions for mainstreaming LCSA. Complementary information that supports the scoring on LCSA studies in developing countries is given in Figure 29.5.

Table 29.1 Summary of the assessment scoring of mainstreaming conditions in countries with at least a life cycle network, life cycle database, or LCSA publications

(a)		(b)		(c)		Total (0–6)
Studies (0–3)	Data (0–2)	Database name	Network (0–1)	Network name	Total (0–6)	
<b>Latin America &amp; the Caribbean</b>						
1	1	-	1	Argentinian LCA network (2023)	3	
3	2	Banco Nacional de Inventários do Ciclo de Vida (SICV Brasil, 2023)	1	Brazilian Association for Life Cycle Assessment (ABCV) (2023)	6	
				Rede de Pesquisa em Avaliação de Impacto do Ciclo de Vida (RAICV) (2023)		
				Rede Empresarial Brasileira de Avaliação de Ciclo de Vida (2023)		
1	1	-	1	Red ACV Chile (Chilean LCA network) (2023)	3	
1	1	-	0	-	2	
1	0	-	1	Red Cubana de Análisis Ciclo de Vida (2023)	2	
1	2	Amaru Database (2023)	1	Red Ecuatoriana de Ciclo de Vida y Economía Circular (2023)	4	
1	0	-	1	Red Guatemalteca de Ciclo de Vida (2023)	2	
1	2	Mexicanuh Database (2023)	1	Red Mexicana de Análisis de Ciclo de Vida (2023)	4	
1	2	PeruLCA Database (2023)	1	Red Peruana de Ciclo de Vida y Ecología Industrial (PELCAN) (2023)	4	



(a)		(b)		(c)		Total (0-6)
Studies (0-3)	Data (0-2)	Database name	Network (0-1)	Network name	Total (0-6)	
<b>East Asia &amp; Pacific, Central Asia, and South Asia</b>						
China	3	2	eBalance Database (2023)	0	-	5
India	2	0	-	0	-	2
Indonesia	2	2	ILCAN Database (2023)	1	Indonesian Life Cycle Assessment Network (2023)	5
Malaysia	2	2	MY-LCID Database (2023)	0	-	4
Pakistan	1	0	-	0	-	1
Thailand	3	2	The National LCI Database for Sustainable Development (THIS, 2023)	1	Thai LCA network (2023)	6
Vietnam	2	0	-	0	-	2
<b>Sub-Saharan Africa</b>						
Mauritius	1	0	-	0	-	1
Mozambique	1	0	-	0	-	1
South Africa	2	1	-	0	-	3
<b>Middle East &amp; North Africa</b>						
Iran	2	0	-	0	-	2
Tunisia	1	0	-	0	-	1

Highlights of the assessment of mainstreaming conditions presented in Table 29.1 are the following:

- With a score of “6”, Brazil and Thailand are considered as having the most conducive mainstreaming conditions, with a national database, life cycle networks (in Brazil more than two) that promote life cycle thinking, and numerous LCA, S-LCA, and LCC studies published, including some on LCSA.
- China and Indonesia follow closely with a score of “5”.
- Countries with minimum conditions for establishing LCSA are Ecuador, Mexico, and Peru due to the existence of national databases and life cycle networks. Malaysia also shows a score of “4” due to having several publications (including on LCSA) that provide a source of local data.
- Supported by the activity of national life cycle networks or publications, countries scoring “3” are becoming increasingly mature when it comes to sustainability topics and, hence, are on the road to adopting LCSA. These countries are South Africa, Argentina, and Chile.

## APPROACHES FOR EXPANDING LCSA IN THE REGIONS

Based on the understanding of the level of mainstreaming conditions in the regions and the priorities identified, the next step in this chapter is to come up with possible approaches for upscaling LCSA practice and the number of key multipliers as well as target audiences for LCSA in the regions.

### Articulation with National Policies on SCP and SDGs

The Global Strategy for Sustainable Consumption and Production (SCP) foreseen for the decade 2021–2030 (UN, 2022) is the basis for National Action Plans on SCP. The National Action Plans on SCP are intended to identify key priority activities and tasks to implement and promote SCP in developing countries, enhancing sustainable lifestyles and improving the quality of people’s lives in moving towards a circular economy. Governments can promote the use of LCSA for identifying priority sectors, products, and materials as a support tool for a National Action Plan. By applying LCSA, key activities and tasks can be identified for addressing the most relevant issues – or hotspots – of selected priority products and materials, not only from an environmental but also from a social and economic perspective. This process will enforce SCP.

The SCP National Action Plans are part of a country’s efforts to achieve Agenda 2030 and the Sustainable Development Goals (SDGs) (UN, 2015). Since 2015, the SDGs have become well known, being part of the international sustainable development agenda that encompasses environmental, economic, and social targets under 17 goals (see Chapter 1). Unlike the Millennium Development Goals (MDGs), which only addressed socio-economic targets centering heavily on poverty reduction, SDGs not only call for the development agenda to be implemented in industrializing countries but also include a request for all states in the world to integrate environmental concerns into their socio-economic priorities.

By considering all dimensions of sustainability based on life cycle thinking, LCSA is seen as a promising framework (Backes and Traverso, 2022). However, to become an operational

approach supporting the implementation of SDGs, LCSA needs to overcome the limitation of there being no consensus on combinations of LCSA indicators that can be linked to SDGs (Backes and Traverso, 2022). The challenge is that SDGs are framed in terms of policy outcomes instead of mid- or endpoints as required by LCSAs. Moreover, LCSA does not yet allow simultaneous operational assessment of specific SDGs, their targets, their indicators, and the resulting trade-offs.

A first effort at an LCA-based assessment of SDGs was made by Weidema et al. (2020), who identified three groups of inventory indicators related to the organization's contribution to the SDGs. These inventory indicator groups are labeled as "How much do you pay," "Whom do you pay," and "How much shared value do your indirect expenditures and behavior create," and these are further described and illustrated with examples of inventory indicators for selected topics related to sustainable development cases. Through these examples, the authors further clarify how the selected topics monitored via the inventory indicators and through different impact pathways can influence the SDGs. So, for example, links between LCA impact categories and targets of SDGs like SDG 6 (UN, 2015) on clean water and sanitation can be established.

It is not easy to provide a clear future outlook based on the latest literature report studies. Still, a clear direction can be seen and is already provided for some SDGs (e.g., SDG 12 on responsible consumption and production and SDG 13 on climate action) (Backes and Traverso, 2022).

Previous works (notably from Weidema et al. (2020) and Backes and Traverso (2022)) suggest that LCSA can be performed by non-experts and be endorsed as an assessment methodology when implementing the SDGs, as these do not require any specific approach.

This is a key finding to be taken into consideration by potential users in low- and middle-income countries with insufficient local capacities.

### **Prioritization of Key National Sectors**

For expanding LCSA in the regions, it would be crucial to focus at the start on sectors of greater national/local interest, such as waste management, building, and energy.

It is worth noting that the majority of initial LCSA developments identified correspond to a group of countries considered, according to the World Bank, as upper-middle-income countries, followed by some lower-middle-income ones, as shown in Figure 29.7.

LCSA approaches addressing the priorities of low-income countries are emerging. An area growing in relevance is nutritional LCA (nLCA), which is being led by the Food and Agriculture Organization (FAO), an intergovernmental organization. nLCA is a priority area with relevant results, particularly for countries with vulnerable food security schemes, that can ensure minimum nutritional levels for a country's population. The FAO report by McLaren et al. (2021) addresses opportunities and challenges in integrating environment and nutrition in the life cycle assessment of food items. This report is a consensus-building project to agree on best practices for environmental and nutritional life cycle assessment methodology and identify future research needs.

The integration of environment and nutrition in the life cycle assessment of food items is an incomplete approach to LCSA as, while this considers a social aspect, that is, nutrition, and the environmental aspect too, the economic aspect will need to complement these studies for it to become a complete LCSA (e.g., in line with the Life Cycle Initiative's principle on completeness (Valdivia et al., 2021)).



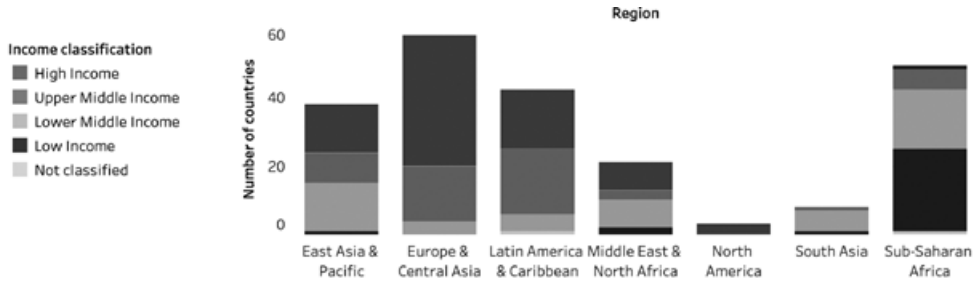
*Notes:*

Disclaimer: The boundaries, tones of gray, denominations, and any other information shown on this map do not imply, on the part of the World Bank Group, any judgment on the legal status of any territory, or any endorsement or acceptance of such boundaries.

Parts of the world that are not discussed in this chapter appear with the same light tone.

Source: World Bank (2022).

*Figure 29.7a World Bank country classification by income level*



Source: World Bank (2022).

Figure 29.7b World Bank country classification by income level

### Tailored LCSA Approach – Key LCSA Principles Supporting the Expansion at Regional Level

The Life Cycle Initiative developed ten principles to support the increased application and use of LCSA (Valdivia et al., 2021) worldwide. Based on the research of Leroy-Parmentier et al. (2023) and Backes et al. (see Chapter 10), it is acknowledged that a stepwise and tailored approach to the principles can enhance their application, particularly in the regions where resources are lacking.

According to Leroy-Parmentier et al. (2023), the level of application of these principles in the 193 publications researched is varied. The following principles were identified to be more broadly disseminated in LCSA practice worldwide than others: LCSA structure *following the ISO framework*, *completeness* by considering the three sustainability pillars, supporting *transparency* by providing information on the models and data sources used, clarification and communication of *trade-offs* identified, and consideration of relevant *stakeholders' perspective*.

LCSA approaches tailored to low- and middle-income countries can support leapfrogging LCSA practices by applying the principles where more experiences of using LCSA exist (see the five principles previously identified). This means conducting LCSAs that consider impact assessment models tailored for local data on priority sectors (waste management, building, energy, and food nutrition). In the absence of social life cycle databases, it is crucial to get access to studies on local stakeholders' issues, for which key local stakeholder groups need to be first mapped and then assessed (following tailored stakeholder research approaches such as interviews of representatives in their local languages). In line with the transparency principle, it is strongly recommended that new local data produced is shared as part of the LCSA study (e.g., as supplementary information). A reader-friendly presentation of results and trade-offs identified is of utmost importance for promoting well-informed decision-making and communication, which should be conducted in the local language as much as possible.

The application of the most broadly disseminated LCSA principles worldwide serves thus as guidance for upscaling and leapfrogging LCSA developments in low-income and middle-income countries.

## S-LCA Datasets

S-LCA data availability remains a challenging area. Currently, S-LCA databases do not provide specific or local data, explaining their limited use. In this regard, it is worth noting that only three S-LCA pilot cases out of nine used the SHDB to identify potential hotspots (Life Cycle Initiative, 2022). SHDB only provides country-level information (Benoît-Norris and Norris, 2015). A similar database is PSILCA (Maister et al., 2020), which uses a more recent Input-Output (I-O) model than the first version of the SHDB.

Our analysis shows that PSILCA and SHDB should develop more indicators tailored for the sectors prioritized in the low- and middle-income countries. Another option is for individual actors in the regions or life cycle networks to take up this task, particularly those with existing local databases (see Table 29.1 with eight national databases identified in low- and middle-income countries).

## Roles of National/Regional Networks

As identified in the assessment of the mainstreaming conditions, insufficient local capacities have limited the development of local data and applications of LCSA. Based on the experience of LCA expansion in low- and middle-income countries, local life cycle networks can effectively promote multi-stakeholder platforms supporting the adoption of LCA in decision-making processes. According to this experience, academia typically serves as a multiplier of LCA efforts. Countries with one or more existing operational networks (e.g., regularly hosting life cycle-related events) and supported with LCA databases clearly evidence sufficient capacities for upscaling LCA and extending into the LCSA field. When several countries with mainstreaming conditions scoring 3+ are located in proximate locations, a positive regional impact due to enhanced synergies takes place, such as in the case of the Iberoamerican Life Cycle Network (2023), which was created to become the regional hub for Latin America and is currently internationally recognized. The Iberoamerican Life Cycle Network (2023) comprises 11 life cycle networks and 11 founders (six female). Every two years, it organizes the International Conference of Life Cycle Assessment in Latin America (CILCA), which covers, among others LC-related topics, LCSA cases.

Thailand is among the countries with the most advanced mainstreaming conditions, which could make it a potential hub of expertise to support upscaling LCSA among neighboring countries in South East Asia.

An important aspect of being considered for robust, enhanced capacity growth is the gender balance in training and research activities and LCSA practices. The current proportion of female authorship of publications in low- and middle-income countries, which stands at 20–25%, cannot be considered “balanced.” While it is acknowledged that female membership in life cycle networks is improving in some regions (the Iberoamerican Life Cycle Network has more than 50% female membership), it is clear that more efforts need to be made in this area. Improving women’s participation in LCSA activities will also contribute to SDG 5, which aims to “achieve gender equality and empower all women and girls.”

## CONCLUSIONS

From the above, it becomes clear that for LCSA methodologies to be applied in the regions a tailored approach is required with enriched data sources focusing on energy, waste, and building sectors first, and then on food and industrial systems. Very relevant also in relation to efforts to enhance capacities is the notable gender gap, the narrowing of which could help such endeavors.

From the LCSA mainstreaming conditions assessment, it is also evidenced that very few developing countries have currently acquired the conditions that allow mainstreaming LCSA practice. The Iberoamerican Life Cycle Network and more advanced countries, including China, Brazil, Thailand, Indonesia, and South Africa, can serve as hubs for regional upscaling. Countries with minimum capacities regarding LCA, due to existing national databases, are Ecuador, Peru, Malaysia, and Mexico. In this last group of countries, targeted efforts are recommended, which can be supported by their life cycle practitioners at the individual expert level or associated with a life cycle network.

## NOTES

1. A HDI is a summary composite measure of a country's average achievements in three basic aspects of human development: health, knowledge, and standard of living.
2. A composite life cycle sustainability index integrates multiple criteria into a composite index by aggregating absolute scores and the relative balance of the multiple criteria.

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