Supplementary material

Figure S1. Methodology to find LCSA-related papers

The rationale behind selecting Scopus and Google Scholar as the main citation indexes is that both are the most common search engines used by researchers. First, we put the keywords “Life Cycle Sustainability Assessment” into the Scopus database, with the temporal limitation from the year 2007 to 2018. We included all types of documents, i.e., article, review, book chapter, conference paper, letter, and editorial. Among the 191 papers found, the second stage was done by screening and scrutinizing them thoroughly in their main body text (not in their abstract). We then excluded 83 papers that do not include analysis of LCA, LCC, or S-LCA in their body text, and had 108 papers remaining. In the third step, we similarly put the keywords “Life Cycle Sustainability Assessment” into Google Scholar, with the time range from 2007 to 2018. In the fourth step, we scrutinized closely the papers found in the first 200 papers in the first 20 pages of Google Scholar (one page includes 10 papers). We, again, excluded 133 papers that were not linked to LCA, LCC, or S-LCA in their main body article, and we had 67 papers remaining. Last, we combined the papers found from Scopus (83 papers) and Google Scholar (67 papers). At the end, we found that there were 51 intersecting LCSA-related publications from Scopus and Google Scholar, 57 publications solely from Scopus, and 16 solely from Google Scholar (see Figure 3 for the illustration). In total, we had 124 publications. These publications also include grey literature, such as reports and working group work from government or reputable organizations.

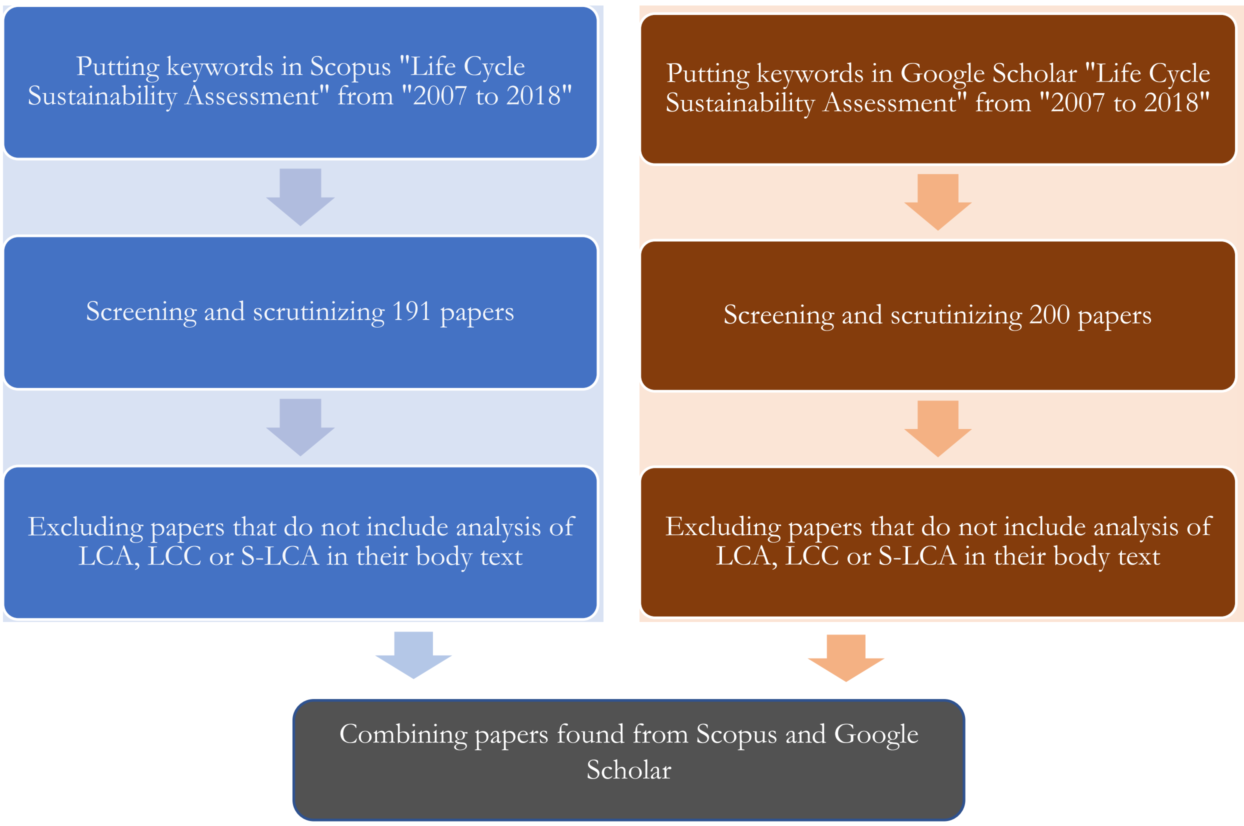

Figure S1. Methodology to find LCSA-related papers

Figure S2. Illustration of the inclusion of LCSA-related papers

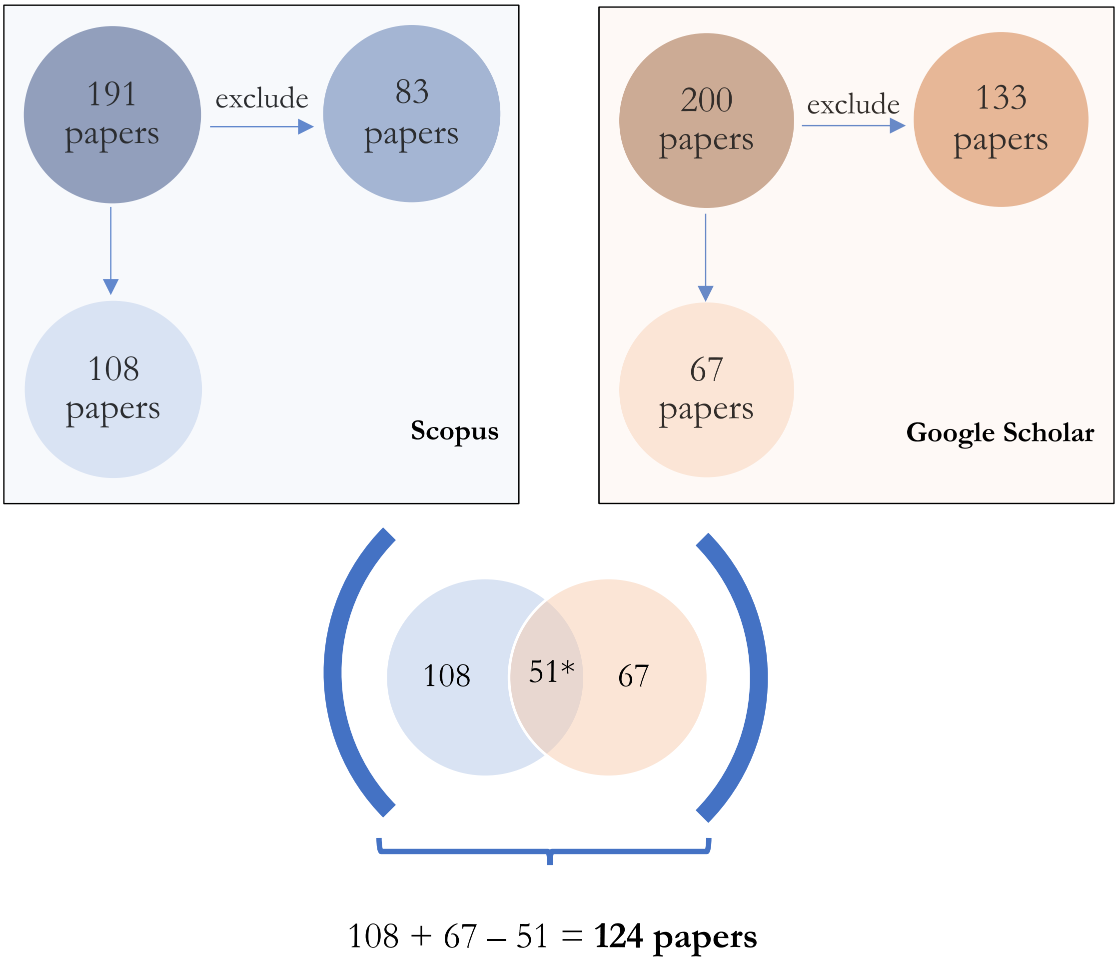

Figure S2. Illustration of the inclusion of LCSA-related papers (* similar papers found in both Google Scholar and Scopus)

Table S1. Highlight of LCSA-related studies

This supplementary material (Table S1) provides a summary of the literature review conducted for LCSA-related articles, including case studies and methodological ones. Each summary of the article contains information on the goal and scope of the study, life cycle inventory analysis (data collection sources), life cycle impact assessment, methodology, main results, and challenges addressed.

#	Artic-les	Area	Title	Goal	Functional Unit		The scope considered																		Life cycle inventory analysis (data collection sources)			Life cycle impact assessment			Methodology	Main results	Challenges
							Extraction			Produc-tion			Transpor-tation			Construc-tion/ Manufac-turing			Use/ Opera-tion			End-of-Life											
							Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc			
1	(Onat et al. 2016)	Electric vehicle (*case study*)	Integration of system dynamics approach toward deepening and broadening the life cycle sustainability assessment framework: A case for electric vehicles	to quantitatively assess three sustainability dimensions of electric vehicles with various scenarios by considering macro-level impacts and evaluating their dynamic relationships in sustainable transportation context	N	broad functional unit taking into account the interactions between three aspects of sustaina-bility	N	N	N	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N	N	US EPA, LAVE-trans model, Oak Ridge National Laboratory	TBL-LCA model	US Social Security	CO_2 emission, particulate matter formation (PMF), photoche-mical oxidant formation (POF), etc.	vehicle ownership costs, contribution to GDP, etc.	Contribu-tion to employ-ment, human health impacts	Quantification of macro-level sustainability aspects was performed by using causal loop diagram and model formulation based on the parameters in transportation sector such as average annual vehicle miles traveled, the sales of new vehicles, efficiency of fuel, population, carbon emissions from certain life phases (vehicle manufacturing and operation, etc).	Many but the authors stressed the importance of capturing dynamic interactions among the sustainability indicators.	To increase accuracy and reduce the uncertainty, some model validation methods were used i.e., ANOVA, two-sample Kolmogorov-Smirnov, Shapiro-Wilk.
2	(Gemechu et al. 2017)	Electric vehicle (*case study*)	Geopolitical-related supply risk assessment as a complement to environmental impact assessment: the case of electric vehicles	to integrate resource criticality evaluation into LCA under the LCSA framework	Y	one electronic vehicle	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	US Geological Survey database, UN Comtrade database, World Bank database for WGI (World Bank)			geopolitical-related supply risk			The calculation method used was based on the equation of geopolitical-related supply risk or resource criticality called "GeoPolRisk".	Many but to name a few is the conventional metals depletion indicator. For instance, as employed by ReCiPe, it has weaknesses that is partially addressed by the GeoPolRisk approach. This result could perform better on the mapping critical material flows.	The geopolitical supply risk aggregated for a number of platinum group metals or rare earth elements is not examined at individual metal elements.
3	(Ren, Ren, Liang, Dong, et al. 2016)	Energy and industrial system (*case study*)	Multi-actor multi-criteria sustainability assessment framework for energy and industrial systems in life cycle perspective under uncertainties. Part 1: weighting method	to develop a novel life cycle multi-criteria sustainability assessment method with central focus on using an improved interval AHP to better weight the criteria	Y	1 t of product produced by these six different energy and industrial systems	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	-	-	-	PCOP, GWP, AP, etc.	investment cost (IC), net present value (NPV) and internal rate of return (IRR), etc.	added job (AJ), impact on local culture (ILC), etc.	A methodology for multi-actor multi-criteria sustainability assessment of energy and industrial options has been developed in this study. The traditional extension theory has been modified to address the uncertainty issues. The proposed method can rank the alternative energy and industrial systems with the decision- making matrix.	It can result more accurately the willingness and preferences of decision-makers.	This study does not address the methodology used for identifying the classical fields which seperate the sustainability into different levels.
4	(Ren, Ren, Liang & Dong 2016)	Energy and industrial system (*case study*)	Multi-actor multi-criteria sustainability assessment framework for energy and industrial systems in life cycle perspective under uncertainties. Part 2: Improved extension theory	to assess sustainability of industrial systems and alternative energy in life cycle thinking by multi-actor multi-criteria sustainability assessment to address the uncertainties	Y	1 t of product produced by these six different energy and industrial systems	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	-	-	-	Idem.				Multiple decision-makers are not allowed to take part in the assessment process. Yet, the method has the capability to reach sustainability assessment under uncertainties.	Idem.
5	(Kempen et al. 2016)	Kitchen set (*case study*)	Using life cycle sustainability assessment to trade off sourcing strategies for humanitarian relief items	to conduct LCSA of sourcing scenarios for a core relief item in a humanitarian supply chain including management and logistics (supply chain sustainability)	Y	A kitchen set enabling the storing and cooking of food and water	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	interviews, company records, and online databases			human health, ecosystem diversity, resource availability using ReCiPe method	transportation cost, procure-ment costs	working condition, health and safety, etc.	UNEP-SETAC guideline was used as a guide. The results were analyzed using ReCiPe method. Two sourcing scenarios identified: one international and one local.	Many but the authors pointed out on the importance of the research on the humanitarian supply chain context and in the emerging economics.	Data quality reporting has bias due to the local suppliers who collected the data. The accuracy of the social analysis is subjective as data of different functional units are collected for the different subcategories.

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6	(Sou et al. 2016)	Waste manage-ment (*case study*)	Sustainability assessment and prioritisation of bottom ash management in Macao	to conduct sustainability assessment on bottom ash management with five different scenarios	Y	1 tonne of MSW	N	N	N	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	on-site investigations and various references and databases			climate change, ecosystem quality, human health and resources	cost and benefit	integrity and acceptabi-lity	Five different incinerator bottom ash management scenarios were applied. LCA was carried out with modified localised HRA. CBA was applied representing economic assessment. For social assessment, fuzzy set theory and AHP were conducted.	Many but the main point is that this approach try to give decision makers information to compare different management scenarios using tools and implement a localised approach.	-
7	(Helbig et al. 2016)	Carbon fibers (*case study*)	Extending the geopolitical supply risk indicator: Application of life cycle sustainability assessment to the petrochemical supply chain of polyacrylonitrile-based carbon fibers	to extend the formulation of geopolitical supply risk indicator including domestic production multi-stage supply chains.	N	-	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	PCI report, United Nations Commodity Trade, World bank			human health, ecosystem service and natural resources	geopolitical supply risk	geopolitical supply risk	Quantification of geopolitical supply risk are applied on multi-stage supply chains for 54 countries. It is an extension of the previous work on Geopolitical Supply Risk methodology for assessing global production and trade patterns for different commodities.	Geopolitical Supply Risk (GPSR) factors for 54 countries in six supply chain scopes are quantified. It provides four different supply risk patterns.	-
8	(Azapagic et al. 2016)	Energy systems (electricity mix) (*case study*)	Towards sustainable production and consumption: A novel DEcision-Support Framework IntegRating Economic, Environmental and Social Sustainability (DESIRES)	to assess sustainability performance in sustainable production and consumption scope	N	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	Data reported in Stamford and Azapagic, 2014			GWP, depletion of minerals and metals, ecotoxicity, etc	fuel price, levelised costs	total employ-ment	Multi-attribute decision analysis using equal weighting were applied with different stakeholder preferences (expert stakeholder preferences and public preferences). A novel decision-support framework incorporating three domains of sustainability called DESIRES has been developed.	The approach allows stakeholders to understand their sustainability preferences and the opinions of others to help to reach a consensus.	-
9	(Cihat, Kucukvar & Tatari 2016)	Electric vehicles (*case study*)	Uncertainty-embedded dynamic life cycle sustainability assessment framework: An ex-ante perspective on the impacts of alternative vehicle options	to improve the body of knowledge at current sustainability assessment frameworks for alternative vehicle technologies	N	-	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Various data (mostly other journal articles)	Transporta-tion data book	-	GHG emission, carbon fossil fuel, water footprint, hazardeous waste, etc.	GDP, foreign purchase, profit, etc.	Employ-ment, tax, injuries, etc.	Two MCDM methods were utilized to rank different types of conventional and alternative passenger vehicles in the US, the Intuitionistic Fuzzy MCDM and the Technique for Order-Preference by Similarity to Ideal Solution or TOPSIS. Seven different vehicle types with respect to the US vehicle market were identified with an average and a 100% solar electricity generation mix scenario).	Many however this study primariliy is about the ranking of alternative vehicle technologies and the dominance/contribution analysis in the sustainability triangle.	Social indicators selected were macro-level social indicators.
10	(Gumus et al. 2016)	Wind energy (*case study*)	Intuitionistic fuzzy multi-criteria decision making framework based on life cycle environmental, economic and social impacts: The case of U.S. wind energy.	to assess sustainability performance of wind energy by using environmentally extended input–output based life cycle assessment (EE-IO-LCA) tools	N	-	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Data from various databases	Data from various databases	Expert opinion	GHG, land, water and energy, etc.	profit, import, etc.	Employ-ment, tax, income, etc.	EE-IO-LCA was carried out for off-shore wind turbine and a 9-step fuzzy MCDM tool was also performed.	The results were obtained, considering the weight of each identified criterion in each life cycle phase.	The uncertainties might come from errors in modeling and data gathering.

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11	(Touceda et al. 2016)	Housing retrofit (*case study*)	Modeling socioeconomic pathways to assess sustainability: A tailored development for housing retrofit.	to assess sustainability complex processes in building retrofit and to guide policy making process in house retrofitting	Y	the housing unit (the entire building in this case), the household, and the ensemble of retrofitting works, repair and maintenance	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	EN 15804 (CEN 2012) and EN 15978 (CEN 2011)	EN 15804 (CEN 2012) and EN 16627 (2015)	SHBD, EN 15804 (CEN 2012) and EN 16309 (2014)	Climate change, human health, etc.	retrofit cost, fuel cost	health of workers, contribution to growth, household poverty, etc.	Various methods were applied for assessing environmental, eonomic and social aspect. Some guidelines were also adopted, i.e. EN 15804 (CEN 2012), EN 16627 (2015) and EN 16309 (2014)	The results could show the comparison between generic hypotheses which are frequently used in policy making studies and in household situations.	This case study was only limited to certain housing stock and must be further compared to other typologies. More different variables need to considered the discount rate, price increase and remaining service life.
12	(Pizzirani et al. 2016)	Forestry (*case study*)	The distinctive recognition of culture within LCSA: Realising the quadruple bottom line.	to capture cultural aspects in LCSA	Y	the three forestry scenarios (i.e. use of 1 ha of unmanaged land)	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	modelled data, publications, reports and the ecoinvent v3.1. database			GHG, energy use, etc.	profit, production cost, etc.	Employement	A LCSA case study was conducted participatorly with a mixed methods approach. Cultural Indicator Matrix was also utilized. Research was performed in cooperation with main members of New Zealand indigenous community.	The method helps the participants to perform progressively towards representing culture in LCSA with transparent and distinct way. This study performs an inclusion of a cultural compliance process for the forestry activities the product`s life cycle.	-
13	(Luu & Halog 2016)	Rice husk bioelectricity (*case study*)	Life Cycle Sustainability Assessment: A Holistic Evaluation of Social, Economic, and Environmental Impacts	to compare sustainability performance of Vietnam rice husk based electricity vs. coal-fired	Y	1 MWh, and an economy wide scale of 9.46E+07 MWh which is equal to around 500 MW of installed capacity of bioelectricity	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	ecoinvent, the Prosuite Decision Support System (DSS), with OpenLCA software	the Prosuite Decision Support System (DSS), with OpenLCA software	SHDB, feasibility reports of power plant and other pertinent literature	human health, ecosystem loss, etc.	benefit and cost	child labor, total hours of employment and of knowledge intensive jobs, etc	A LCSA for comparative study of two types of electricity were performed.	The comparative results were presented between two types of electricity in different impact assessments.	-
14	(Cihat, Kucukvar, Tatari, et al. 2016)	Passenger cars (*case study*)	Combined application of multi-criteria optimization and life-cycle sustainability assessment for optimal distribution of alternative passenger cars in U.S.	to improve current sustainability assessment framework for passenger vehicles by maximizing the optimal vehicle distribution based on the source of electric power supply and prime concerns of policy makers	N	-	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Kucukvar and Tatari, 2013; Onat et al., 2014d			GHG, energy use, etc.	foreign purchase, profit, etc.	GDP, employment, injury, etc.	A multi-objective optimization model was carried out to calculate the optimal distribution of passenger cars in the U.S.. It was performed by considering environmental and socio-economic goals and their weights.	Many, however the authors pointed that this study shows the results by considering the macro-scale socio-economic impacts that many studies ignored to incorporate.	Incapability to capture global trade-links between trading partners and to include other uncertainties from temporal and spatial aspects (effects of behaviors on driving, fuel consumption, charging times and locations, performances of battery, regional TBL impact variations, etc.)
15	(Clímaco & Valle 2014)	Wind and Thermo-Electric Power Stations (*case study*)	MCDA and LCSA	to test preference aggregation of S-LCA in LCSA of power stations in Brazil	N	-	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	Y	N	N	N	-	-	interviews, on-site observation and secondary sources (companies' sustainability reports)	-	-	local community category (except indigenous rights and delocalization & migration)	S-LCA with impact matrix and open exchange interactive multi-criteria software was performed.	The potency of multi-criteria approach (the aggregation of preferences) applied in the complex problem were presented and discussed.	-

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							Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc			
16	(Kalbar, Birkved, et al. 2016)	Resource consump-tion (*non-case study*)	Weighting and aggregation in life cycle assessment: do present aggregated single scores provide correct decision	to perform and answer a question: do aggregated single scores give correct decision support?	N	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	1000 selected data from Danish residents			ecosystems, human health and resources	-	-	A linear weighted sum (LWS) method was performed with distance-based approach.	A distance-based multiple attribute decision-making method for acquiring single scores were proposed.	The ReCiPe single-score calculation method does not quantify dominating alternatives (alternatives having high values across all endpoints) nor the mutuality of the aggregated indicators.
17	(Galán-martín et al. 2016)	Electricity technolog ies (*case study*)	Enhanced data envelopment analysis for sustainability assessment: A novel methodology and application to electricity technologies.	to enhance data envelopment analysis in the area of electricity technologies	N	-	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	-	-	-	GWP, ozone deple-tion, acidifica-tion, etc.	capital cost, operation and mainte-nance cost and fuel cost	Employ-ment, injury, human toxicity, etc.	Data envelope analysis for macro scale assessment was conducted.	This approach can handle macro scale sustainability aspect and enable the ranking of alternatives with quantitative targets	Incapability to integrate the unit in the assessment. Efficiency scores are sensitive to the number of inputs, outputs, and size of sample.
18	(Moslehi & Arababad i 2016)	Energy Systems (*case study*)	Sustainability Assessment of Complex Energy Systems Using Life Cycle Approach-Case Study: Arizona State University Tempe Campus.	to assess sustainability performance of a complex energy systems	Y	Not clearly mentioned	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	site-specific data and normalized data on systems performance gathered from literature			GHG emissions, water pollution, air pollution, etc.	initial, operational, mainte-nance costs, etc.	safety assess-ment, system accounta-bility, etc.	Multi-criteria sustainability appraisal framework was conducted with two scenarios: Business as Usual (BAU) and Climate Neutrality Roadmap (CNR). Sustainability index calculation was also utilised.	System boundaries are significant to help stakeholders to comprehend consequences of a specific action.	-
19	(Atilgan & Azapagic 2016)	Electricity genera-tion (*case study*)	An integrated life cycle sustainability assessment of electricity generation in Turkey	to assess sustainability performance of electricity sector in Turkey	Y	generation of 1 kWh of electricity in Turkey	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	various sources and many asssump-tions were made	Sener and Aksoy (2007)	OECD data	abiotic depletion potential, GWP, etc.	capital and annualised costs, levelised costs, etc.	Employ-ment, accident, etc.	Multi-criteria decision analysis was performed with ranking and weighting of different options.	The ranking of the electricity options and the weights of importance placed on the sustainability aspects could help to understand the most sustainable option.	Data were limited. Complete data were needed for future works with more regionally-specific and recent ones.
20	(Huang & Mauerhof er 2016)	Heat pump (*case study*)	Life cycle sustainability assessment of ground source heat pump in Shanghai, China	to assess sustainability performance of ground source heat pump	N	Not clearly mentioned	Y	Y	Y	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	literature review and site investigation			GWP, EP, AP	cost, benefit, net benefit	Employ-ment	GaBi was used to performed the LCA. LCC and employment rate were also accounted.	An innovative sustainability method was proposed with its practicality	Information and data could not be gathered sufficiently.
21	(Cihat, Gumus, Kucukvar , et al. 2016)	Vehicle techno-logies (*case study*)	Application of the TOPSIS and intuitionistic fuzzy set approaches for ranking the life cycle sustainability performance of alternative vehicle technologies	to assess sustainability performance using TOPSIS and intuitionistic fuzzy set.	N	Not clearly mentioned	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	(Kucukvar and Tatari, 2013; Onat et al., 2014a)			GHG, energy, water, etc.	foreign purchases, business profits, GDP, etc.	Employ-ment, tax, injury, etc.	Institutionistic fuzzy MCDM and TOPSIS were carried out for LCSA with the Life Cycle Sustainability Triangle (LCST) for interpretation.	A combination of applying both LCSA and two MCDM methods (Intuitionistic Fuzzy MCDM and TOPSIS) were presented to give a rank the sustainability performance of different vehicle types in U.S.	Additional key social indicators were suggested for future studies, i.e. safety, air pollution health impact, employment levels by income and gender group, affordability, equity, etc.
22	(Dong & Ng 2016)	Building (*case study*)	A modeling framework to evaluate sustainability of building construction based on LCSA.	to develop a LCSA framework and apply it for building construction project	Y	Not clearly mentioned	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Question-naire survey to the project manager	HKHA 2005	HKHA 2005	Climate change, ozone depletion, etc.	Costs of material and service	child labor, fair salary, working hours, etc.	Three different models were employed to perform LCSA: the environmental model of construction (EMoC) (Dong and Ng 2015a), cost model of construction (CMoC), and social-impact model of construction (SMoC) (Dong and Ng 2015b) representing each pillars of sustainability.	Material stage on the environmental and social aspects in building construction project gets less attention.	Data availability was a major concern affects the quality of assessment and the adoption of non-local LCI databases and national social statistics were questioned by stakeholders.

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23	(Genctürk et al. 2016)	Building (*case study*)	Life cycle sustainability assessment of RC buildings in seismic regions	to quantify sustainability performance on reinforced concrete (RC) buildings	Y	The structural components of the entire building	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	various sources and references	Building cost database, RS Means Database	ATC (Applied Technology Council)	Environmental impact of construction through EPS (environmental performance score)	initial and end-of-life costs	deaths and injuries	LCSA combined with seismic and earthquake hazard assessment on comparisons of alternative designs.	The results showed that the cost, environmental and social impacts in the structural use stage could be highly lowered by applying a resilient plan.	Uncertainty has been found in repair cost, environmental impact and downtime values due to inavailability of data and the assumptions used in the definition of damage states.
24	(Steen & Palander 2016)	safeguard subjects (*non-case study*)	A selection of safeguard subjects and state indicators for sustainability assessments.	to identify safeguard subjects and suitable indicators for sustainability assessment using an interpretation of the Brundtland definition and to explore how indicators selected in this way differ from others.	N	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	-	-	-	energy, mineral, water, etc.	financial, income	human health, jobs, occupation, knowledge, peace, social security, etc.	A top-down approach was used for identification of indicators for LCSA.	The comparison between capital categories for assessing sustainable development by UNECE and safeguard subject in this work were presented as well as the comparison between UNEP/SETAC's impact subcategories, safeguard subjects and state indicators in this work.	Some simplifications and also complications has been found in defining certain state indicators.
25	(Gemechu et al. 2017)	Raw material (*case study*)	Import-based Indicator for the Geopolitical Supply Risk of Raw Materials in Life Cycle Sustainability Assessments.	to enhance import-based Indicator for the Geopolitical Supply Risk of Raw Materials in Life Cycle Sustainability Assessments using the principle of MFA	N	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	various databases (ecoinvent, GaBi, etc)	UN Comtrade	UN Comtrade	Import-based Indicator for the Geopolitical Supply Risk of Raw Materials			Various different methods were used for assessing the supply risk of resources.	Many but the authors pointed out the importance of geopolitical and associated indicators to solve issue within the LCSA where the current impact assessment practice in LCA lack of the AoP (area of protection) of natural resources.	Data availability and lack of different supply chain levels are main challenges.
26	(Wagner et al. 2016)	Electronic systems (*case study*)	Evaluation of Indicators Supporting the Sustainable Design of Electronic Systems.	to evaluate indicators for sustainable design of electronic systems.	Y	relative energy consumption (relative indicator) the light output	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	GaBi database	ProBas online database (Prozessorientierte Basis daten)	ProBas online database (Prozessorientierte Basis daten)	Cummulative energy demand, carbon emission, etc.	cost	-	Indicator matrix linking resource and emission impacts to three life cycle stages was used and case scenarios were also built for the hotspots analysis.	Many but the authors assessed the complex product structures and used ascertained data for transparency.	The main challenges is data availability and therefore lower the certainty for the inkterpretation.
27	(Kalbar, Karmakar, et al. 2016)	Wastewater treatment (*case study*)	Life cycle-based decision support tool for selection of wastewater treatment alternatives.	to achieve life cycle-based decision-making tool for selecting wastewater treatment	N	-	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	site specific WWTP, various statistics and databases	site specific WWTP	site specific WWTP	global warming, eutrophication, etc.	cost, benefit, etc.	labor or manpower	Decision support tools (DSTs, TOPSIS, vector normalization and scenario selection were utilized.	Many but the authors proposed that selecting correct wastewater treatment technologies is challenging task however this approach can robust computational platform that help significantly in the decision making process.	A participation of a large group of stakeholders might be difficult in real situation. More site-specific information is needed. There is also a risk of selecting an incorrect set of indicators that could lead to a biased decision.
28	(Keller et al. 2015)	Biorefineries (*case study*)	Integrated life cycle sustainability assessment—A practical approach applied to biorefineries.	to conduct LCSA as ex-ante decision support in biorefineries	N	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	provided by all partners in biorefinery plants	provided by all partners in biorefinery plants	ILO databases	climate change, resource depletion, energy, etc.	NPV, IRR, profit, etc.	rural development, feedstok, labor conditions, etc	LCSA was combined with ex-ante decision support model called integrated life cycle sustainability assessment (ILCSA)	A result from interim assessment methodologies for individual sustainability aspects was presented.	Comprehensive result was shown it was yet incapable of delivering simple answer.

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							Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc			
29	(De Luca et al. 2015)	Citrus farming (*case study*)	Social life cycle assessment and participatory approaches: A methodological proposal applied to citrus farming in Southern Italy	to integrate the results from previous work on LCA and LCC to conduct S-LCA as whole LCSA	Y	One ha of clementine orchard	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	primary and secondary sources			climate change, water, etc	various costs	health and safety, etc.	S-LCA was perfomed with AHP and more locally relevant criteria was used.	The integration of LCC and LCA with S-LCA results could deliver a broader impact categories.	There is a risk for double counting considering various aspects considered.
30	(Ren et al. 2015)	Bioethanol (*case study*)	Prioritization of bioethanol production pathways in China based on life cycle sustainability assessment and multicriteria decision-making	to verify the combination between MCDM model and LCSA for decision-making by exploring three alternative pathways for bioethanol production	Y	1 t bioethanol	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	statistics and surveys			climate change, ozone depletion (OD), human toxicity, etc.	capital, feedstock, production, operation and maintenance costs.	working condition, cultural heritage, government, etc.	LCSA was combined with MCDM methodology, i.e. (AHP) and the VIKOR method.	Many but the authors proposed this approach could help to identify alternatives to select the most sustainable option.	Uneasiness for users to conduct the MCDM method.
31	(Yu & Halog 2015)	Solar Photovoltaic (*case study*)	Solar Photovoltaic Development in Australia—A Life Cycle Sustainability Assessment Study.	to undertake the sustainability assessment of solar photovoltaic in UQ Australia	Y	1 kWh of electricity produced by UQ Solar	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	European database	various databases	various databases	climate change, abiotic depletion, acidification, etc.	cost, tax, discounted cost, etc.	supplier relationship, transparaency, etc	Financial metrics were quantified using SAM, including LCOE, electricity cost per year and other economic parameters.	Many, however the authors intended to identify the sustainability performance of solar PV installations on the project level to better understand whether solar photovoltaic is desirable or not.	Expert review and stakeholder participation were suggested to better understand the issue.
32	(Hossaini et al. 2015)	Buildings (*case study*)	AHP based life cycle sustainability assessment (LCSA) framework: A case study of six storey wood frame and concrete frame buildings in Vancouver.	to perform LCSA with combination of AHP to identify sustainability performance of building	N	-	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	database	survey	survey	global warming potential, acidification, eutrophication potential, etc.	initial, maintenance costs, etc.	occupant comfort, safety, and affordability.	LCSA was combined with AHP to evaluate the sustainability performance of a building.	The results of life cycle impacts for each unit area of buildings were comparatively presented. Building alternatives have various impact level with regards to different (sub)criterias.	No agreed method has been found to ensure the relative importance of different impacts. Decison making based on AHP, in some cases, creates ambiguity and redundancy among different criteria. More advanced MCDM techniques was recommended by the authors.
33	(Peukert et al. 2015)	Modular machine (*case study*)	Addressing Sustainability and Flexibility in Manufacturing Via Smart Modular Machine Tool Frames to Support Sustainable Value Creation.	to perform LCSA to understand sustainability performance in manufacturing via smart modular machine tool frames	N	-	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	database	database	SHBD	carbon footprint	Manufacturing cost	salary	LCSA was undertaken with emergy-based assessment and AHP analysis. GaBi software was used with CML characterisation factor.	Production phase accounts the highest contribution for carbon footprint while fair wage assessment have been found more significant for the sensor nodes (electronic components). A sustainability footprint as a result of carbon footprint, fair wage and manufacturing cost assessment was presented.	More indicators need to be included in the assessment. Difficulties on comprehending the results since in-depth ecological knowledge is required.
34	(Stamford & Azapagic 2014)	Electricity (*case study*)	Life cycle sustainability assessment of UK electricity scenarios to 2070	to evaluate the life cycle sustainability of various electricity scenarios for the UK	N	per unit of electricity generated	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	Stamford and Azapagic, 2014	survey	survey	GWP, AP, EP, ODP, etc	capital, operational, fuel and total costs	salary, employment, worker injuries, etc.	Varying scenarios and sub-scenarios on electricity mix and national target were undertaken in the assessment.	Overall, the sustainability impacts of the five electricity scenarios were compared and presented.	The challenges are related to the lack of data on the technologies that are not commercially available yet and the uncertainty on the technological development.

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							Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc			
35	(Akhtar et al. 2015)	Sewer pipe material (*case study*)	Life cycle sustainability assessment (LCSA) for selection of sewer pipe materials.	to perform LCSA to select best sewer pipe materials based on their sustainability performance	Y	the 3 m length and 400 mm diameter of sewer pipes of different materials with the same design life of 100 years.	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	N	emergy database, SimaPro 7.1 inventory data	various sources	various sources	global warming, NOx emission and SOx emission, etc	initial, mainte-nance, repair and replacement cost	-	LCA and LCC were performed and then combined with AHP analysis.	Environmental and economic assessment result on four types of sewer materials were presented along with each pros and cons.	The challenges are linked to the subjectivity of the evaluation and limited researches on documenting the uncertainties in emergy-based LCA.
36	(Martínez -Blanco et al. 2014)	Fertilizers (agricul-ture) (*case study*)	Application challenges for the social Life Cycle Assessment of fertilizers within life cycle sustainability assessment.	to face application challenge of S-LCA within LCSA through case study in fertilizers.	Y	1 ton of tomato (henceforth, 1 ton of fertilized tomato)	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	ecoinvent, ELCD, national databases, etc.	ecoinvent, ELCD, national databases, etc.	SHBD	GWP, ODP, human toxicity, etc.	fertilizer market price, price of transpor-tation, extra application costs	various impact assessment from SHDB	E-LCA, LCC and S-LCA was carried out. Additionally, SHDB was performed for S-LCA.	Many but to sum up, the results of E-LCA, LCC and S-LCA in a integrated fashion were presented using LCSD.	The primary challenge is related to the uncertainty in data collection since several indicators in SHDB are not filled with real but extrapolative data and few sector data are available for most of issues, sectors and countries. Challenges are also dealt in the integration of the scopes of the three tools.
37	(Kucukva r, Gumus, et al. 2014)	Pavement (*case study*)	Ranking the sustainability performance of pavements: An intuitionistic fuzzy decision making method.	to quantify sustainability performance with an intuitionistic fuzzy decision making method	N	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	various databases			carbon emission, water footprint, energy consump-tion, etc.	import, tax, income, etc.	injuries	TOPSIS method based on intuitionistic fuzzy entropy was performed to select the most appropriate asphalt.	The results of decision making method applied in MCDM problem were presented in order to weight the best of the pavement alternatives.	The uncertainty will increase when EIO model use the aggregated sector data where several sub-sectors are evaluated under the same main sector. The subjectivity of expert judgment for sustainability indicators also affects the uncertainty
38	(Lu et al. 2014)	Waste Electrical and Electronic Equip-ment (WEEE) (*case study*)	Reusability based on Life Cycle Sustainability Assessment: case study on WEEE	to assess sustainability performance and reusability of WEEE	Y	the typical components of 100 waste mobile phones	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	practical field investi-gation, RCEES, and other databases	practical field investiga-tion	practical field investiga-tion	climate change, acidifica-tion, ecotoxicity, etc	costs	Employ-ment, housing, and education	LCSA was used to assess the reusability of waste mobile phone. Three assessments were conducted, environmental reusability assessment, economic reusability assessment and social reusability assessment.	Many but overall the results show the comparison of the two systems of telephone end of life treatment: (a) components reuse (b) materials recovery mode.	The definition on what is good or bad and what is positif and negative impact in the case of whether job creation is more important than the health risk or not is the challenge faced. More other macro or micro factors need to be concern i.e. reusability time range, physical condition and technology innovation speed. Improvements is needed in the integration methods of three sustainability pillars.
39	(N. C. Onat et al. 2014)	Buildings (*case study*)	Integrating triple bottom line input-output analysis into life cycle sustainability assessment framework: The case for US buildings.	to integrate triple bottom line input–output analysis into LCSA framework.	N	-	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Environ-mental Protection Agency (EPA), the US Depart-ment of Energy (DOE)	Bureau of Economic Analysis (BEA), the Federal Highway Adminis-tration (FHWA),	the US Energy Informa-tion Adminis-tration (EIA)	GHG, water, energy, etc.	GDP, import, business profit	injury, income, govern-ment tax, etc.	Triple Bottom Line (TBL) LCA, a type of input-output based LCA model was used to incorporate the environmental impacts and financial flow as well as the social state.	Many but overall results show the various TBL impacts of residential and commercial buildings.	Limited data are available for certain indicators. Aggregated sector data that contain many other less-relevant sub-sectors are used thus increases the uncertainty. Certain impacts are assumed to happen in domestic level thus a global view of those impacts are highly reccommended for the future study.

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							Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc			
40	(N. Onat et al. 2014)	Passenger vehicle (*case study*)	Towards Life Cycle Sustainability Assessment of Alternative Passenger Vehicles.	to perform LCSA of alternative vehicle technologies in macro-level	Y	1 mile of vehicle travel	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	various databases			GHG, water, energy, etc.	GDP, profit, import, etc.	Employ-ment, human health, injury, etc.	TBL indicators were used to measure the sustainability performance of passenger vehicles with two scenarios: when no additional infrastructure requirement exists and when electricity to power BEVs and PHEVs are produced.	The quantified results on economic, social, and environmental impacts are presented based on each life cycle phase and two scenarios considered.	Limited number of processes considered could be a drawback of this approach. The selection of processes to be included is also quite subjective thus could increase the uncertainty.
41	(Kucukvar, Noori, et al. 2014)	Pavement (*case study*)	Stochastic decision modeling for sustainable pavement designs.	to address the direct and indirect environmental, economic, and social impacts (Triple-Bottom-Line (TBL)) in assessing sustainability performance	Y	one-km pavement using sustainability weights ranging between 0 and 1	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	National renewable energy database and others	WIOD, GTAP, BEA database	various databases	GHG, water	GDP, import, tax, etc.	Employ-ment, injury, etc.	A hybrid TBL-LCA was performed and combined with MCDA for hot- and warm-mix asphalt.	Varying results on macro-level environmental and socio-economic assessment were presented in each life cycle stage. At last, the optimal percentages of each alternatives were presented.	The variability of input parameters need to be considered since it affects the certainty.
42	(Valdivia et al. 2013)	Marble slab (*case study*)	A UNEP/SETAC approach towards a life cycle sustainability assessment—our contribution to Rio+20	How to perform sustainability performance considering all the possibility of technique in LCSA?	Y	1 m3 of marble types A, B, C and D	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	not mentioned specifically (qualitative and quantitative data were used)			CO_2, N_2O, water, etc	wage cost, material cost, etc	Employ-ment, working hours, presence of child working, etc	LCSD methodology was used to compare sustainability performance of product systems where expert and non-expert stakeholders were involved.	Many but in general LCSD marble slab results and scores were presented based on the types and and overall index.	Data unavailability is a major issue. Linkages of the indicators to some techniques need to be regarded.
43	(Pesonen & Horn 2013)	Biodiesel (*non-case study*)	Evaluating the Sustainability SWOT as a streamlined tool for life cycle sustainability assessment.	to evaluate sustainability performance by using SWOT analysis	N	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	readymade databases, survey or case-specific data			GHG, raw materials, NOx, SOx	various costs	social welfare and incomes	SWOT was used to have more streamlined assessment.	The results of the analyses on the usability of SWOT in both business and LCSA framework have positive remarks.	Even though this approach is adapted to the logic sense of the business stakeholders but it does not follow strictly the impact assessment guideline. The inclusion of uncertainty in this approach should be streamlined
44	(Wood & Hertwich 2013)	Economic (*case study*)	Economic modeling and indicators in life cycle sustainability assessment	to model economic indicators in life cycle sustainability assessment and answer a question of whether the methods applicable to consequential and attributional LCSA	Y	1 GWh of electricity	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	-	EXIOPOL database	-	-	cost (labor and capital), taxes, etc.	-	Economic modeling and calculation using Taylor series expansion of the Leontief inverse with the representation of variables in a hybrid IO LCA model was performed for macro-scale economic formulation.	The cost of indicator results was presented as well as indicator results on productivity measurements. This appoach is believed could be used for consequential approach of LCC in LCSA.	The uncertainty found in this study is not methodological but rather the availability of relevant data.
45	(Ostermeyer et al. 2013)	Building refurbish-ment (*case study*)	Multidimensional Pareto optimization as an approach for site-specific building refurbishment solutions applicable for life cycle sustainability assessment	to perform sustainability performance with multidimensional Pareto optimization	N	-	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	ReCiPe ecoinvent database, IPCC 100, CED	-	-	-	-	-	This method used was a multidimensional Pareto optimization combined with LCC, LCA and the first stages of a social assessment.	The performance of 729 normalized results were presented from 6 measurements and 3 possible options for LCC and ReCiPe indicators in site in Paris/France. Single technology measurements for the marked concepts were also deliberated.	Technologies and measurements considered in the approach were limited. Some that are not considered in the approach might create a gap and thus could miss the suitable options. The results were presented with relative values (percentages). The calculation used was the static values. No dynamic approach scenarios was involved. The social aspect was also left out of the formulation.

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							Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc			
46	(Foolmaun & Ramjeawon 2013)	PET bottles (*case study*)	Life cycle sustainability assessments (LCSA) of four disposal scenarios for used polyethylene terephthalate (PET) bottles in Mauritius	to understand sustainability performance of different disposal scenarios for reused PET bottles	Y	1 tonne of post-consumer PET bottles	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	not mentioned	not mentioned	surveys, site-specific data and other databases	climate change, ecotoxicity, ozone depletion, etc.	operating and mainte-nance costs	almost all S-LCA indicators (UNEP) were covered.	LCA+LCC+S-LCA was performed with combination of AHP and was applied in four different four disposal scenarios.	The summary of results for the three disposal facilities and final ranking were presented. Sensitivity analysis was also shown.	-
47	(Vinyes et al. 2013)	Cooking oil waste manage-ment (*case study*)	Application of LCSA to used cooking oil waste management.	to perform LCSA in cooking oil waste management	Y	the UCO generated in a neighbour-hood of 10,000 inhabitants for 1 year in the city of Barcelona	N	N	N	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	ecoinvent database	not mentioned	entities and organisa-tions	GWP, ODP, abiotic depletion, etc.	personnel cost, transpor-tation cost, collection and storage cost, etc.	Employ-ment, equality, public commit-ments to sustaina-bility issues, etc.	LCA, LCC and S-LCA were carried out.	Many but the authors emphasized on the selection of UCO collection system that performs best in the three assessments.	The uncertainty exists in the weighting of each indicators within each and among three sustainability dimensions. Second uncertainty is linked to the connection of social indicators and its fine-tuning to the functional unit.
48	(Manzardo et al. 2012)	Hydrogen technolo-gies (*case study*)	A grey-based group decision-making methodology for the selection of hydrogen technologies in life cycle sustainability perspective	to carry out a grey-based group decision-making methodology for the selectiohydrogen technologies	N	-	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	not mentioned	not mentioned	survey to stakehol-ders	water	costs	job creation, working condition, social influences, etc.	LCA, LCC and S-LCA were performed with stakeholder involvement on the decision-making group. Twelve scenarios on the hydrogen technology development were considered.	The result of twelve different scenarios of hydrogen technologies was presented for selecting the most suitable hydrogen production as well as for delivering the interpretation for decison-makers.	Uncertainty and availability of data & models are the big chunk. The subjectivity in the qualitative evaluation also play part increasing the uncertainty.
49	(Stamford & Azapagic 2012)	Electricity option (*case study*)	Life cycle sustainability assessment of electricity options for the UK	to perform LCSA to assess electricity options for the UK	N	-	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	various databases			GWP, marine ecotoxicity potential, etc.	fuel price, levelised costs, etc.	Employ-ment, injuries, accidents, human toxicity, etc.	Methodological framework used was a life-cycle approach to assess techno-economic, environmental and social sustainability on various electricity options in the UK.	Many however the results were presented in each aspect such as techno-econoomic, environmental, and social sustainaibility and were divided based on the higher and lower value preferred.	-
50	(Traverso, Finkbeiner, et al. 2012)	Natural hard floor covering (*case study*)	Life Cycle Sustainability Dashboard	to present LCSA result effectively and communicatively	Y	cubic meter of slab	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	not mentioned	not mentioned	social data from each province with stakeholder involve-ment	energy, GWP, HTP, PO, acidifi-cation, eutrophi-cation, etc.	extraction, manufac-turing, finishing, waste disposal, electricity costs and revenues	salary, employ-ment, injury and accident, equality and social benefits.	LCA+LCC+S-LCA was undertaken. Various indicators in each aspects were used.	Many however the authors emphasized on the application of LCSD as a tool to present the interpretation results of sustainability performance of a product.	The unavailability of data was a major challenge.
51	(Traverso, Asdrubali, et al. 2012)	Photovol-taic modules (*case study*)	Towards life cycle sustainability assessment: An implementation to photovoltaic modules.	to carry out sustainability assessment of the assembly and production of photovoltaic (PV) modules.	Y	1 m2 of modules	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Ecoindi-cator	not mentioned	interview and question-naires	GWP, ecotoxicity, acidifica-tion, land use, etc.	cost	working hours, benefits, wage, etc.	LCSA was carried out and the results were presented using LCSD.	LCSA and LCSD ere used as tools to assess sustainability performance and present the results to policy makers in order to support decison making process effectively.	The overall objective in each aspect is a main challenge. LCA was used clearly for minimizing environmental impacts. For the other two, it depends on the perspectives.
52	(Menikpura et al. 2012)	Solid waste manage-ment systems (*case study*)	Framework for life cycle sustainability assessment of municipal solid waste management systems with an application to a case study in Thailand.	to assess sustainability performance of municipal solid waste treatments in Thailand.	Y	Manage-ment of one tonne of generated MSW in Nthaburi within the integrated system.	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	ecoinvent and BUWAL	not mentioned	not mentioned	CO_2, CH_4, N_2O, CO, NH_3, H_2S, Nox, Sox, VOCs, land, etc.	income and cost	labor force, community participa-tion, living standards	Integrated systems of LCA, LCC and S-LCA was undertaken with different formula and theoretical concept.	Results on the damage to ecosystem & abiotic resources, net LCC of the technologies and income & job creation were presented.	Certains informations could be lost when data is aggregated was the primary challenge.

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53	(Nzila et al. 2012)	Biogas produc-tion (*case study*)	Multi criteria sustainability assessment of biogas production in Kenya.	to perform sustainability assessment on biogas production	Y	1 m3 of biogas	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	various databases and interview		-	CED, GHG, energy	total investment cost, labor cost	-	Multi criteria sustainability assessment characterisation was carried out with environmental, technological and economic sustainability evaluation.	Multi-criteria sustainability assessment spider-gram comparing the performances with respect to the unit square of area used in biogas production was presented.	-
54	(Schau et al. 2011)	Remanu-factured alterna-tors (*case study*)	Life Cycle Costing in Sustainability Assessment—A Case Study of Remanufactured Alternators	To answer a main question : how is the application of LCC as part of a broader sustainability assessment where S-LCA and LCA are also combined.	Y	100,000 km	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N	N	N	N	N	N	-	ILO databases and others	-	-	cost for warranties, transport cost, labor cost, cost of energy, etc.	-	LCA-type LCC method was applied. The main focus of method is rather about the complex parameters need to consider in the remanufactured alternators.	The results were presented based on the remanufacturer perspective and from the user perspective.	The uncertainties found are linked to the ambiguity of cost (positive or negativea) and the economic grwoth (rather a mean or an end). The AoP for economic assessment is needed.
55	(Moriizumi et al. 2010)	Plantation on waste-lands (*case study*)	Simplified life cycle sustainability assessment of mangrove management: a case of plantation on wastelands in Thailand	to conduct streamlined LCSA of mangrove management	Y	the plantation area of 1000 ha would be divided into 10 plots and mangroves would be planted on one plot every year	N	N	N	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N	Data and information of plantation were collected in five provinces			carbon emission	cash flow	Employ-ment	Assessment on the sustainability aspects were conducted by looking at the net carbon sequestration, employment, and cash flow.	The results were presented based on the site-specific investigation and sensitivity analysis were also undertaken.	Data availability is the biggest challenge in this study.
56	(Zhou 2007)	Fuel (*case study*)	Life cycle sustainability assessment of fuels.	to apply multi-criteria assessment on fuels based on sustainability approach.	N	-	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	N	N	N	N	various databases	various databases	-	GWP, energy and non-renewable resources	costs	-	Multi-criteria analysis was performed based on sustainability indicators (environment, economy, energy and renewability indicators) in six cases.	Many but the authors highlighted the interpretation of sustainability index and evaluation of the cases.	Macro-indicators used to assess the fuel performance could lower the scientific value of the assessment.
57	(Wulf et al. 2017)	Rare Earth Perma-nent Magnets (*case study*)	Lessons Learned from a Life Cycle Sustainability Assessment of Rare Earth Permanent Magnets	to address certain methodological challenges of LCSA application.	Y	1 kilogram (kg) of magnet	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	many sources and reports	many sources and reports	SHDB	fossil fuel depletion, climate change, ozone depletion	OPEC, CAPEX indicators	forced labor, wages, employ-ment and other risks based on SHDB	LCSA was applied with different normalization, aggregation methods, and weighing factors.	The results of the comparison of the three magnet production systems were shown with different normalization and weighting methods.	Insufficient of data and methodological documentation increases the uncertainty. What the future sustainable trend should go in certain impact categories could be problematic, for instance, "*does a high risk of unemployment imply the need to invest in that country to improve the situation or does it suggest that a country with a lower risk should be sought*".
58	(Benedict 2017)	Energy alterna-tives (*case study*)	Understanding Full Life-cycle Sustainability Impacts of Energy Alternatives	to understand and emphasize on life-cycle sustainability impacts of energy alternatives	N	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	-	-	-	-	-	-	It is a comparative study of LCSA applied in energy alternative sector.	A suggestion for future work was made that coupling life cycle sustainability with scenario planning will be beneficial for energy-related policy making.	-
59	(Mehmeti et al. 2016)	solid oxide fuel cells (*case study*)	Life cycle sustainability of solid oxide fuel cells: From methodological aspects to system implications	to review the status of LCA and LCC of solid oxide fuel cells and apply the methods under LCSA	Y	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	-	-	-	-	-	-	Literature review was done focusing on the system boundary, impact assessment & method and economic aspect.	The results show about the status of each stage of LCA in solid oxide fuel cells application along with eco-efficiency and impact assessment.	Lack of methodological consistency was one of the main points where the attention needs to be paid to.

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							Extraction			Production			Transportation			Construction/ Manufacturing			Use/ Operation			End-of-Life											
							Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc			
60	(Kamali et al. 2016)	soybean farming systems (*case study*)	Evaluation of the environmental, economic, and social performance of soybean farming systems in southern Brazil	to evaluate sustainability performance of soybean farming systems with stochastic model	Y	1 ton of GM, Non-GM, or organic soybeans	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N	ecoinvent database	survey, site visit	various databases	GWP, land occupation and energy use	profitability	Employment	Environmental, economic and social life cycle assessment were done with stochastic model using Monte-carlo simulation.	The results of the simulated sustainability performance for the three soybean farming systems were presented based on the performance indicators. The cumulative distribution function was also shown.	Data limitation is the biggest issue.
61	(Li et al. 2017a)	Solar Photovoltaic (*case study*)	A Regional Life Cycle Sustainability Assessment Approach and its Application on Solar Photovoltaic	to assess sustainability performance of regional solar photovoltaic deployment	Y	The generation of 1 kWh electricity	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	ecoinvent database	not mentioned	survey and stakeholder consultation	GWP, energy, AP, HTP, EP	reliability and profitability	land use, local community and fuel poverty	A framework for assessing three dimensions of sustainability were proposed. The indicators used were selected basing on some criteria, i.e. no double counting, the indicators must be quantifiable, applicability and easiness to understand.	Sustainability performance results were presented in lower and higher value preferred.	-
62	(Schaubroeck 2017)	Theoretical article (*non-case study*)	A Revision of What Life Cycle Sustainability Assessment Should Entail Towards Modeling the Net Impact on Human Well-Being	to revisit again on how to evaluate the sustainability properly	N	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	-	-	-	-	-	-	-	A roadmap on what we need to focus to enhance the LCSA. (1) how to frame which areas should be sustained (2) how to account for the interconnectedness among AoPs (e.g., the interconnectedness between ecosystems and human well-being); and (3) how to assess both benefit and damage to the AoPs properly.	-
63	(Tarne et al. 2017)	Review article (*non-case study*)	Review of Life Cycle Sustainability Assessment and Potential for Its Adoption at an Automotive Company	to review LCSA and the opportunity to adopt it in automative company	N	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	-	-	-	-	-	-	-	Current state of LCSA in automotive industry was presented as well as bibliometric study.	The inconsistency of the execution in three methods, the low maturity of S-LCA, different way of result interpretation were the challenges found in this study.
64	(Wang et al. 2017)	Concrete structure (*case study*)	Life cycle sustainability assessment of fly ash concrete structures	to assess sustainability performance of fly ash concrete	Y	The production of 1m3 FA concrete	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	various databases, ICE, ecoinvent, CLCD, etc.	Yu et al.	stakeholder survey	climate change, respiratory effect, terrestrial acidification, etc	cost of material, transportation and energy consumption	living condition, health, education, culture and necessities	Many calculation model was used in each stage, i.e. impact assessment, durability analysis, single-objective optimization. Also, quantitative calculation process of SLCA of FA concrete was performed.	Overall environmental and economic results were presented with characterization, weighting results, and social life cycle impact of concrete with different substitutions.	Two suggestions were made: 1. Uncertainty modeling for future work is needed. 2. A number of a key factors of sustainability should be added.
65	(Hapuwatte et al. 2016)	Manufactured product (*case study*)	Total life cycle sustainability analysis of additively manufactured products.	to assess economic, environmental and social performance of manufacturing product using product sustainability index.	N	-	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	Y	Y	Y	not mentioned	not mentioned	not mentioned	Environment sub-index score	economy sub-index score	social sub-index score	Product sustainability index method was performed with normalization and weighting.	The results were presented in various sub-index scores for each components for each sustainability dimensions.	The subjectivity of the weighting and normalization and the relativity to its components make the analysis incomparable to each other. The inability of this approach to take the quantity of production as a factor that affect sustainability was a drawback.

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66	(Hake et al. 2017)	Alkaline Water Electrolysis (*case study*)	Towards a Life Cycle Sustainability Assessment of Alkaline Water Electrolysis	to assess the sustainability performance of alkaline water electrolysis	Y	The production of 1 kg H2 (33 bar, 40 °C, 99.8% purity)	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	data from project and ecoinvent database	EU Energy	SHDB	climate change, ozone depletion, terrestrial acidification, etc.	investment cost, levelised cost, electricity cost, etc.	labor, risk of excessive working time, wage, right of strike, etc.	LCSA was performed with additional step of normalization, weighting and aggregation	Performance matrix was shown comparing the results in three different countries in three aspects of sustainability.	-
67	(Li et al. 2017b)	Photovoltaic power generation (*case study*)	Life cycle sustainability assessment of grid-connected photovoltaic power generation: A case study of Northeast England	to evaluate the sustainability performance of photovoltaic power generation	Y	one unit of electricity produced by the selected solar PV system	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	GaBi professional v6.115 and Ecoinvent 3.1	various sources	stakeholder consultation	material circularity, energy payback, GWP, AP, EP, ODP	cost, financial feasibility	fuel poverty, employment provision	LCSA was undertaken with 17 indicators selected, 7 addressed techno-economic aspects, 6 examined environmental aspects and 4 assessed social aspects	Results on various indicators were presented in different stages and at the end sustainability ranking of solar PV systems was given.	Some bias-factors existed due to the sensitivity analysis carried out and the cross-validation method need to be employed for future works.
68	(Nguyen et al. 2017)	Biodiesel (*case study*)	Inclusive impact assessment for the sustainability of vegetable oil-based biodiesel e Part I: Linkage between inclusive impact index and life cycle sustainability assessment	to assess the trade-off between benefit and disadvantages of the biodiesel system	N	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	various sources			embodied energy, GWP, HTP, AP, EP, ADP,TEP	extraction, manufacturing, finishing, waste disposal, electricity costs and revenues	salary, employment, accident, discrimination, social benefit	Inclusive impact index was undertaken to assess sustainability performance of biodiesel along with LCA, LCC and S-LCA.	No result was presented since it is the first part of work that only covers goal and scope definition and life cycle inventory analysis stage.	The absence of social issues in the method is part of the limitation found in this study. The model used also face uncertainties due to the choices, model, parameter, spatial variability, etc.
69	(Wu 2017)	green building (*case study*)	Agent-Based Modeling of Temporal and Spatial Dynamics in Life Cycle Sustainability Assessment	to address the temporal, spatial, and behavioral dynamics in LCSA by using agent based modeling.	Y	construction of 100 new buildings	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	hypothetical example with assumptions applied from various sources.			waste	cost	incentive	Hypothetical example was applied and ABM was incorporated in the LCSA model.	Annual LCSA results on waste, cost and incentive from all of scenarios applied were presented. Spatial distribution of green building development in various scenarios for certain years was also shown.	This study does not specify the type of the building and stakeholders involved. The unoccupied cells were also considered available to be developed. The oversimplification of the variety of cost difference that is related to building types, geographical location, green building technology applied, infrastructure and policy.
70	(Martín-gamboa et al. 2017)	energy system (*non-case study*)	A review of life-cycle approaches coupled with data envelopment analysis (DEA) within multi-criteria decision analysis for sustainability assessment of energy systems	to review the application of LCSA with DEA in energy system	N	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	-	-	-	-	-	-	review on the 62 articles in the topic of sustainability assessment and MCDA of energy systems were conducted.	The growing role of MCDA in energy policy and the increasing number of the LC+DEA application make LCSA methodological framework is highly needed.	-
71	(Smetana, Sergiy; Tamasy, Christine; Mathys, Alexander; Heinz 2016)	food industry (*case study*)	Regionalized Input-Output Life Cycle Sustainability Assessment: Food Production Case Study	to perform Regionalised LCSA with regionalised environmental, economic and social data for LCSA in few regions in Germany	N	-	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	official statistical sources.			biotic resources	monetized value	-	Regional Sustainability Assessment Methodology (RSAM) with input output analysis was performed	Biotic resources, absolute and monetized value comparison of food industry for certain regions in Germany were shown.	The detail data is reccommended for the future work to expand RSAM method to become more holistic. The dynamic time series application is also needed to have more precise result.

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							Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc			
72	(Ya-Ju Chang, Sabrina Neugebauer et al. 2017)	Manufac-turing (*non-case study*)	Life Cycle Sustainability Assessment Approaches for Manufacturing	to formulate the LCSA framework with the tiered approach.	N	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	-	-	-	-	-	-	Literature review and research needs were presented at LCA, LCC, S-LCA and LCSA as a whole.	The authors emphazised on the importance of LCA for the identification of product and process hotspots for decision making in production development. Tiered approach was also reccommended to be applied.	-
73	(Sánchez Berriel et al. 2018)	Cement (*case study*)	Introducing Low Carbon Cement in Cuba - A Life Cycle Sustainability Assessment Study	to carry out LCSA for assessing sustainability assessment of low carbon cement	Y	The production of one ton of cement	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	not mentioned	not mentioned	not mentioned	climate change, ozone depletion, human toxicity, etc.	monetary, direct, labor cost, etc.	hours of work, health & safety, cultural heritage, local employ-ment, etc.	The adapted LCSA combining LCA, EcLCA and S-CA was conducted.	The results of sustainability performance of three types of cement (Portland cement, blended cement and low carbon cement) were presented.	-
74	(Irene et al. 2017)	olive growing system (*case study*)	Evaluation of sustainable innovations in olive growing systems: A Life Cycle Sustainability Assessment case study in southern Italy	to conduct LCSA with the combination of multicriterial and participative method, the AHP.	Y	1 hectare of cultivated surface	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	specific in-field survey and questionnaires to farmers and workers			climate change, toxicity, land use	profitability, costs, investment feasibility	social health, job opportu-nities, contribu-tion to national welfare	LCSA was conducted with AHP weighting and sensitivity analysis	Integrated sustainability performance of olive growing scenarios was shown. AHP weights of each sustainability dimensions and of each impact categories were also presented.	The uncertainty is related to the assumption of data invariance.
75	(Chen & Holden 2018)	grazing dairy (*case study*)	Tiered life cycle sustainability assessment applied to a grazing dairy farm	to assess sustainability performance in dairy sector	Y	1 kg of fat and protein corrected milk (FPCM) delivered at the farm gate	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	National Farm Survey 2014 and other sources			GWP, AP, EP, mineral extraction, water use, land occupation, etc.	production cost	health and safety, producti-vity of land and labor, work time, fair wage	Tiered LCSA (Neugebauer 2015) was performed and coupled with MCDA.	Mid-point results of impacts and triangle of sustainability to illustrate the iterpretation for each tier was presented.	Uncertainty occurs due to data quality and number of indicators applied in this study.
76	(Xu et al. 2017)	Chemical process (*case study*)	Life cycle sustainability assessment of chemical process: a vector-based three-dimensional algorithm coupled with AHP	to propose 3D methodology of vector-based three-dimensional approach for LCSA in chemical process	N	-	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	literature and LCA databases			GWP, AD, HT, AP, EP	costs, NPV, discounted cash flow	health & safety, social responsi-bility, politcal applica-bility, etc.	LCSA with MCDA was conducted on three alternatives of chemical process	Comparison matrix for scoring the criterion and vector-based results in three alternatives were presented.	The inconsistency of data collected and the subjectivity and vagueness of the expert's judgement were the main challenges found.
77	(Grubert 2017)	Methodo-logical article (*non-case study*)	The Need for a Preference-Based Multicriteria Prioritization Framework in Life Cycle Sustainability Assessment	to involve the subjectivity of the information needed for identifying the parameters of a decision such as prospects to decide, uncertainty, risk attitudes, and preferences	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Participatory decision making including survey and interview was done to see the proof of concept	Aggregated and cluster preference rank values based on the survey were presented. In this LCSA approach, the main aim lies on where different fields of science and inquiry can best contribute.	-

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78	(Albertí et al. 2017)	Review article (*non-case study*)	Towards life cycle sustainability assessent of cities. A review of background knowledge	to analyse how life cycle approach and sustainability assessment has been applied in city	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	This review article explored at the background knowledge of sustainability assessment in the entire life cycle phase as well as at the different scope from construction product up to urban region.	This review article concludes that current sustainability assessment in building missed out the holistic point of view while in urban region missed out the proper guidelines.	Many. One of them is for future work, comparison of the results among different cities or urban regions would be very beneficial for policy or decision makers. Consensus on how to conduct sustainability assessment in urban region is also reccommended.
79	(Akber et al. 2017)	Electricity (*case study*)	Life cycle sustainability assessment of electricity generation in Pakistan: Policy regime for a sustainable energy mix	to carry out LCSA of the electricity sector in order to strengthen policy-making and optimization of the future energy mixes in Pakistan	Y	The generation of 1 KWh of electricity and	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	databases	site-specific interview	site-specific interview	abiotic resource depletion, GWP, AP, EP, etc.	capital, O&M, fuel, annualized and levelized costs	Employ-ment, imported fossil fuel avoided, diversity of fuel supply mix	LCSA was conducted and 20 out of 161 indicators were chosen. These indicators represent indicators related to electricity sector. A scenario for future energy mix was also applied.	The impacts of three pillars of sustainability per functional unit were shown. Besides, the score of sustainability with equal weight to all dimensions was presented along with the score of proposed future electricity mixes.	Scope limitations and data constraints could impose uncertainty. The equal weigthing process of three pillars of sustainability could also affect the uncertainty for policy-making.
80	(Iacovidou et al. 2017)	food waste (*case study*)	A Parameter Selection Framework for Sustainability Assessment	to structure the concept of the resource recovery system using PESTEL (political, economic, social, technological, environmental and legal) analysis	N	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	not mentioned	not mentioned	not mentioned	GWP, ozone depletion, photoche-mical oxidation, AP, EP, HTP, etc.	acquisition cost, operational cost, mainte-nance cost, EoL disposal cost, environ-mental cost	impacts on worker, consumer, local commu-nity, society and value chain	LCSA combined with PESTEL was performed.	The identification of PESTEL parameters related to food waste management system were presented along with relevance ranking and uncertainties from low to high level.	The lack of an MFA to see the the flow of food waste and the subjectivity of ranking process could impose the uncertainty. The links between different value domain were forgotten due to analysis that is done at each domain individually. The transfer of parameters of political, technological and legal into the LCSA domains of sustainability pillars/impacts is uncertain.
81	(Aziz et al. 2016)	Agricultu-ral waste (*case study*)	Life cycle sustainability assessment of community composting of agricultural and agro industrial waste	to understand the sustainability performance of community composting of waste of agriculture and agro-industry by performing a LCSA.	Y	The treatment of one ton of waste	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	field observation, laboratory analysis, interview and literatures			AP, EP, GWP, HTP, POP	capital, operational, mainte-nance, wage and damage costs	child labor, fair salary, employ-ment, accident, health and safety	LCA, LCC and S-LCA was performed using SimaPro software 7.3.3. Two alternatives of composting sytems were considered: powder compost system (PCS) and granular compost system (GCS).	LCSA impact assessment result of PCS and GCS were presented and compared along with normalization and sensitivity results.	LCA, LCC and S-LCA was performed using SimaPro software 7.3.3. Two alternatives of composting sytems were considered: powder compost system (PCS) and granular compost system (GCS).
82	(Boer et al. 2011)	Review article (*non-case study*)	Greenhouse gas mitigation in animal production : towards an integrated life cycle sustainability assessment	to review alternatives to mitigate GHG emissions in supply chain of animal production	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	This review showed that most studies captured production systems in developed countries and on a single indicator, i.e. GHG. They do not taking into account the interconnected effects on other GHGs or with other aspects of sustainability, i.e. economic and social aspect	Consequential setting has never been discussed before and to tackle sustainability challenges in food industry consequential approach is highly reccommended.

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83	(Halog & Manik 2011)	Review article (*non-case study*)	Advancing Integrated Systems Modeling Framework for Life Cycle Sustainability Assessment	to improve integrated methodology by highlighting the strengths of different tools used in sustainability area.	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Different methods were compared and the strengths of each then was analysed to see the opportunity of its use in supporting sustainability decision making.	Integrated sustainability frameworks were provided along with their conceptual, theoretical, empirical and computational background.	The data availability and how to incorporate stakeholder's interest were two main challenges considered in this approach.
84	(Ciroth et al. 2011)	Methodo-logical article (*non-case study*)	Towards a Life Cycle Sustainability Assessment	to introduce the concept of LCSA and acknowledge the previous foundations by leveraging the assessment beyond the environmental aspect only.	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	LCA, LCC and S-LCA was suggested to be carried out together in the same system boundary under the similar functional unit.	Some suggestions on how to perform LCSA and some real examples are provided.	Some challenges addressed are the harmonization of database management system, strengthening the application, developing more streamlined approaches, etc.
85	(Heijungs et al. 2010)	Methodo-logical article (*non-case study*)	Life cycle assessment and sustainability analysis of products, materials and technologies. Toward a scientific framework for sustainability life cycle analysis.	to review the development of frameworks that revolving around LCSA.	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	The review was carried out by addressing the sustainability concept and then life cycle analysis.	Two elements of sustainability and LCA then are combined and general modeling framework was suggested.	LCA, LCC and S-LCA have different satellite accounts to extract indicators thus makes the integration not easy.
86	(Finkbeiner et al. 2010)	Methodo-logical article (*non-case study*)	Towards life cycle sustainability assessment	to explore the recent status of LCSA for products and processes	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Three aspects of sustainability were explored in terms of approachs and methods.	For environmental aspect, well structured LCA is available but not for the other two aspects. Robust methods are needed to measure individual sustainability dimensions.	Comprehensive and undertsandable interpretation and presentation are disirable.
87	(Kloepffer 2008)	Theoreti-cal article (*non-case study*)	Life cycle sustainability assessment of products	to explore the approaches on how to assess sustainability pillars properly and in balance if new product design or improvement of the existing one takes place	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	The analysis was conducted thoroughly for LCA, LCC and S-LCA.	The development was much needed for S-LCA, compared to the other siblings, LCA and LCC.	The biggest challenges lie on the S-LCA method, i.e. how to relate qualitative impacts to the functional unit and how to manage plenty of indicators on social impact.
88	(Jeroen B. Guinee; et al. 2011)	Review article (*non-case study*)	Life Cycle Assessment: Past, Present, and Future	to explore the history and development and current status of LCA	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	The analysis of the recent, current and future development of LCA as an assessment tool.	In the future, LCSA will be tha major assessment that will be used for assessing sustainability of a product or policy. LCSA itself is seen as an approach rather a model.	The main challenge is how to structure, select, and achieve and channel the practicality of the various disciplinary models to different life cycle sustainability questions
89	(Burchart-korol 2011)	Review article (*non-case study*)	Application of Life Cycle Sustainability Assessment and Socio-Eco-Efficiency Analysis in Comprehensive Evaluation of Sustainable Development	to review the current state of frameworks in sustainability assessment.	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	The analysis of current state and methods used in the LCSA was conducted.	A comprehensive and integrative assessment is needed for strengthen the method in order to assess the complexity of sustainability issue.	How to integrate three methods in LCSA remains a significant challenge

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90	(Traverso, Finkbeiner, et al. 2012)	Natural hard floor covering (*case study*)	Life Cycle Sustainability Dashboard	to communicate the LCSA results with direct but comprehensive presentations	N	Not mentioned	Y	Y	Y	Y	Y	Y	-	-	-	-	-	-	-	-	-	-	-	-	site-specific data and various databases			Embodied energy, GWP, HTP, POP, AP, EP	Extraction costs, manufac-turing costs, finishing costs, waste disposal costs, electricity costs, revenues	Employ-ment, number of accidents percentage of child labor labor hours per week	The LCSA was performed and LCSD was tested through a case study.	LCSD is used to present an innovative, applicable and practicable comparison methodology for assessing sustainability performance	The LCSA was performed and LCSD was tested through a case study.
91	(Zamagni et al. 2013)	Theoreti-cal article (*non-case study*)	From LCA to Life Cycle Sustainability Assessment : concept, practice and future directions	to present the current state of sustainability assessment, the concept and practice	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	The current state of each methods in LCSA was discussed and analysed	The development of concept, practice and future directions of LCSA was presented. Some key points are: - The normativity elements in LCSA and the aspects of inter- and intra-generational equity; - The assessment scale - The time horizon - The stakeholders involvement	LCSA was criticized due to the fact that it prevents a complete understanding of the mutual interdependencies of the three domains of sustainability.
92	(Sala et al. 2013)	Theoreti-cal article (*non-case study*)	Progress in sustainability science : lessons learnt from current methodologies for sustainability assessment : Part 1	to identify the characteristics of methods in the sustainability assessment	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	The review lies on the ontological, epistemological and methodological aspects of sustainability in the science context. A meta-review of recent studies on sustainability assessment was also conducted.	Some key features for the improvement of robust sustainability assessment were presented.	Positive impacts should be more promoted by the life cycle-based methodologies so they will not only focus on alternative comparison and avoiding negative impacts.
93	(Cinelli et al. 2013)	Theoreti-cal article (*non-case study*)	Workshop on life cycle sustainability assessment: the state of the art and research needs - November 26, 2012, Copenhagen, Denmark	to analyse the different schools of thoughts on LCSA and frame an agenda for LCSA improvement.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	The review happened around the state of the art, the summary of workshop, and research needs on LCSA.	The main results of the workshops presented were about the farmework, the operationalising of LCSA, sustainability assessment of technologies and ontology, epistemology and methodology of LCSA.	How to effectively present the LCSA result, how to apply LCSA into real application and how to involve stakeholders in the process are the primary challenges discussed in the workshop.
94	(Zamagni 2012)	Theoreti-cal article (*non-case study*)	Life cycle sustainability assessment	to addresss shortly the important developments in LCSA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	It was short address of editor of IJLCA on the recent developments of LCSA	The growing interest of sustainability issue, approach, inherent transdisciplinary nature of sustainability science, and the importance of integration between methods are the main idea addressed.	How to deal with different level of maturity between three methods, with scenario modeling, with consistent integration and with normative positions (values) and empirical knowledge within LCSA are the main challenges mentioned.
95	(Klöpffer & Birgit 2014)	Theoreti-cal article (*non-case study*)	From LCA to Sustainability Assessment	to discuss about the state of the art of LCA, LCC and S-LCA and their combination in LCSA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Three methods representing three pillars of sustainability was carefully analysed in terms of its state of the art and current development and its potency to integrate in one assessment such LCSA.	The capability of LCA to quantify environmental impacts must be supplemented by economic (LCC) and social (S-LCA) aspects.	How to keep the balance between the desired scientific accuracy and practical feasibility remains a main challenge.

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							Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc			
96	(Pizzirani et al. 2014)	Theoreti-cal article (*non-case study*)	Is there a place for culture in life cycle sustainability assessment?	to analyse and discuss the possibility to consider culture in the LCSA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A literature review on the definition of culture and culture involvement in LCA, LCSA and S-LCA as well as some key points to address when assessing the integration of culture in LCA, S-LCA and LCSA was conducted.	A positive benefit of considering culture within LCSA has been seen as a greater resonance of LCSA results with stakeholders. The integration of culture in LCSA could potentially help to protect communities and their diversity.	The main challenges are the lack of recognition in decision-making processes due to culture is often seen as intangible norm, understanding when 'culture' should be differentiate from 'social' also remains, the data gathering, and the diversity of cultures between stakeholders at different scales from local community, regional, to nation.
97	(Sonnemann et al. 2015)	Theoreti-cal article (*non-case study*)	From a critical review to a conceptual framework for integrating the criticality of resources into Life Cycle Sustainability Assessment	to review on the possibility of integrating criticality of resources in LCSA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Review was done by looking at the resource as an area of protection (AoP) in sustainability study. This article also reviewed all of recent criticality assessment studies.	LCA does not capture sufficiently resource criticality assessment even if it is highly important in sustainability aspect. An approach by Graedel et al. (2012) was proposed to evaluate the criticality of resources.	The main challenges lie on a need of a competition factor to evaluate resource depletion by involving resource recycling, substitutability and user adaptation to depletion. The geopolitical supply distribution aspect of resources criticality also need to be considered in LCSA framework.
98	(van Der Giesen et al. 2013)	Methodo-logical article (*non-case study*)	Towards application of life cycle sustainability analysis Revue de Métallurgie Towards application of life cycle sustainability	to apply LCSA framework by evaluating the sustainability performance of solar fuels by implementing first step which is system descriptions	-	Not clearly mentioned	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N	N	N	N	-	-	-	-	-	-	The methodology proposed was consisted of five steps: system description, scenarios, indicators and tools, application of tools, and interpretation of results. This study focuses on the first step: system description.	A general scheme and themes of the system concerned in an LCSA study that need to be addressed were presented. Also, practical approach to conduct and illustrate system description was presented.	-
99	(Finkbeiner et al. 2015)	Methodo-logical article (*non-case study*)	Enhancing the practical implementation of life cycle sustainability assessment e proposal of a Tiered approach	to propose and develop an indicator hierarchy and a stepwise application concept based on the practicality, relevance and method robustness.	-	Not clearly mentioned	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N	N	N	N	-	-	-	-	-	-	Tiered approach was develop to enhance the implementation of indicators and to robust the indicator selection process.	The structure for the tiered approach was presented from sustainability footprint, best practice and comprehensive assessment in order to to improve sustainability assessment towards a more holistic approach away from single aspect assessments.	The new method proposed still does not solve the challenge in the interpretation stage.
100	(Hall 2015)	Review article (*non-case study*)	A transdisciplinary review of the role of economics in life cycle sustainability assessment	to review the application of economic values in LCA and the possibility for environmental LCC as the 'economic pillar' in LCSA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	The review covered the transdisciplinary framework of sustainability assessment, the role of economic values in LCA and economic concepts in ecological economics. A two-stage approach for economic values application in LCSA was proposed.	This paper questioned the reliance of LCA on utilitarianism and valuation using willingness to pay. It also questioned the claim of ELCC as the economic dimension of LCSA.	The current definition of environmental LCC addresses some of the challenges in ontological and epistemological aspect. Existing monetisation and the values of the policy maker need to be accounted to confirm its suitability with sustainability.

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101	(Guinee 2016)	Review article (*non-case study*)	Life Cycle Sustainability Assessment: What Is It and What Are Its Challenges?	to address a significant question: what and how is LCSA practitioners actually applying in real practice	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	This study reviews on two main questions: which definition(s) do researchers in the academia adopt and what challenges do they experience	The review on the case or methodological study was presented. The references were categorised on three groups: study on broadening the impacts, broadening the analysis and deepening the analysis.	The lack of (proper and quantitative) S-LCA indicators, the need for practical (case study) examples, dynamic approach and scenario evaluations, how to interpret LCSA results, how to address uncertainties as well as with value choices, the subjectivity (weighting methods), how to deal with benefits in S-LCA, how to avoid double counting, and how to incorporate different perspectives (producer, customer, societal) on costs in LCC, etc.
102	(Onat et al. 2017)	Review article (*non-case study*)	Systems Thinking for Life Cycle Sustainability Assessment	to discuss the role of systems thinking to deliver tools, methods and disciplines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Bibliometric analysis was carried out in LCSA studies from 2000 to 2017 based on the broadening indicators category, the broadening scope category and the deepening category. The role of system thinking was also discussed.	The results pointed out that LCSA framework could be advanced in these areas (1) regional and global level LCSA models using multi-region input-output analysis (2) dealing with uncertainties in MCDA indicators weighting; and (3) integration of system dynamics modeling to deal with causal relationships of the indicators.	Envisaging the sustainability mechanisms, understanding further parts of the complex systems, and the links to intended sustainability goals were the main challenges mentioned.
103	(Irene et al. 2017)	Review article (*non-case study*)	Life cycle tools combined with multi-criteria and participatorymethods for agricultural sustainability: Insights from a systematic and critical review	to highlight the combination of life cycle approaches with MCDA in agricultural sustainability context	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A systematic and review was done for these parameters: which multi-criterial and/or participatory methods have been linked with LC tools; how is the methodological relationships; how is the involvement of stakeholders; and which synergies have been reached by integrating the methods.	Results of the critical review of the state of the art on LC studies integrating MCDA in agricultural sustainability was presented along with their methodological issues and participative purposes. The discussion lies on the advantages of approaches combination.	The future research proposed was should LCSA is needed to be apply in seperate LC assessement or not considering the communicability of results, usability of specific specialized expertise and use of separate data.
104	(Gloria 2017)	Editorial article (*non-case study*)	Charting the Future of Life Cycle Sustainability Assessment	To address questions: (1) what form should the integrated concept take to include technological, economic, and social assessment of systems? (2) what are the precise classifications of application? Can LCSA be applied at the organizational level or the economy-	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Some issues were mentioned, i.e., : - challenges on broadening of impacts while keeping a comprehensive approach - the communication of LCSA results to policy makers applying weighting concept and addressing the value choices - the incorpartion of technological, economic, and political mechanisms at different levels of analysis by	Some priorities must be given to advance LCSA, i.e. which areas should be identified as main priority to be maintained and how to address the interrelationships of those and furthermore how to integrate both impacts and benefits within LCSA (Schaubroeck and Rugani 2017). To this date, the trend seems to be focus on the prioritization of impacts versus broadening of impacts.

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				wide level? (3) is it possible for LSCA to adapt and adopt methods related to the SDGs to measure progress toward sustainability? (4) will this expansion of E-LCA to LCSA enhance our ability to apply life cycle thinking																												integrating LCA with other types of models - the development of appropriate, quantitative and practical approaches for S-LCA	
105	(Fokaides & Christoforou 2016)	Review article (*non-case study*)	Life cycle sustainability assessment of biofuels	to present the key issues of LCA biofuel production along with the challenges of sustainable biofuel production	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	The main results deliberate the considerations when applying LCA in biomass to biofuel conversion routes in first-, second-, third- and fourth-generation biofuels as well as address key findings of LCA studies in biofuel production, i.e., on energy corps, solid biofuels upgrade, biofuel thermochemical pretreatment or overall impact of biofuel production	The main challenges presented were mainly main challenges for biofuel sustainability, not challenges related to LCSA application.
106	(Ren & Toniolo 2018)	Hydrogen produc-tion (*case study*)	Life cycle sustainability decision-support framework for ranking of hydrogen production pathways under uncertainties: An interval multi-criteria decision making approach	to develop a life cycle sustainability decision-support framework for ranking hydrogen production pathways by combining LCSA and interval MCDM method	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	GWP, AP	Production cost	Social acceptabi-lity, maturity	LCSA was combined with MCDM called improved decision-making trial and evaluation laboratory (DEMATEL). The updated version of DEMATEL method was used to identify the weights of the criteria. The interval of EDAS (Evaluation based on Distance from Average Solution) was also developed for ranking the alternatives for hydrogen production.	The comparison matrix for identifying the relative influences of maturity, energy efficiency, and exergy efficiency on production cost was presented. The average solution of each indicator, the sum weighted positive & negative distance and the integrated priorities of the four alternative pathways for hydrogen production were elaborated.	The recommended multi-criteria decision making method does not provide numerous actors to takepart in identifying and ranking the alternatives.
107	(Hannouf & Assefa 2017)	High-density polyethy-lene (HDPE) (*case study*)	Life Cycle Sustainability Assessment for Sustainability Improvements: A Case Study of High-Density Polyethylene Production in Alberta, Canada	To assess the sustainability performance of the HDPE life cycle by Dow Chemical Canada facility in Alberta, Canada	Y	the production of 1,000 kg of HDPE at Dow Chemical Canada facility	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	Fore-ground: company`s LCI report Back-ground : US LCI database	The prices of materials are obtained from online sources, such as Natural Resources Canada; Natural Gas Exchange INC while labour cost is from Alberta Govern-ment	Results were taken form Hannouf and Assefa 2017	GHG emission (carbon dioxyde and methane)	Costs based on the raw material, energy and labour	Results were taken from Hannouf and Assefa 2017	the strong sustainability model and the Driver–Pressure–State–Impact–Response (DPSIR) framework were employed	LCC results were shown interestingly by from three different perspectives (NG producer, petroleum producer and HDPE producer) and by cost category. Interpretation LCSA results were also presented along with the integrated solution-oriented approach. The latter includes developing sustainability improvement proposals for the background and foreground processes	Interpreting the interdependences between the three assessment results is a challenge, particularly moving from comparative assessment approach to solution-oriented approach

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108	(Ekener et al. 2018)	Transportation fuel (*case study*)	Developing Life Cycle Sustainability Assessment methodology by applying values-based sustainability weighting - tested on biomass based and fossil transportation fuels	To verify the methodology for assessing the sustainability performance of product using different stakeholder views in MCDA	N	-	Y	N	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Various literatures and databases (mostly from ecoinvent)	Literature review	SHDB, SDGs	GWP, water and non-renewable energy consumption	Production and transportation cost	Direct and indirect job	E-LCA was done from well-to-tank and tank-to-wheel while S-LCA consdiered both positive and negative impacts.	The LCSA was weighted based on the sustainability pillars that are focused differently from the values of the stakeholder (Egalitarian, Hierarchist, and Individualist)	The interpretation of LCC results to sustainable development concept remain a challenge. For S-LCA, uncertainty, quality and reability of data used are still questionable because database used in this study is typically slef-reported. For LCA, a challenge to include indirect effect (i.e. indirect land use change) remains exist
109	(Ren & Manzardo 2018)	Industrial systems or chemical industry (*non-case study*)	Multiactor multicriteria decision making for life cycle sustainability assessment under uncertainties	developing a generic multiactor multicriteria decision making (MAMCDM) method for life cycle sustainability assessment (LCSA) of industrial systems under uncertainties	N	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	-	-	-	-	-	-	A method was recommended for ranking the industrial processes under uncertainties in LCSA using a multi-actor multi-criteria decision-making methodology called TODIM with an extended interval	The sustainability decision-making matrix with integrated superiorities of the five electricity scenarios was presented.	There are some interrelationships and interactions among the criteria for sustainability assessment that are usually neglected. The proposed method cannot match with matrix of decision-making with hybrid types.
110	(Zajáros et al. 2018)	Waste water (*case study*)	Life Cycle Sustainability Assessment of DMSO Solvent Recovery from Hazardous Waste Water	Compare the open and closed technology	Y	1 m^3 absorbent	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Database and literature	Database and literature	Database and literature	ADP, GWP, ODP, AP, EP, HT, POP	Cost	the number of employees	The database used was ecoivent, the software used were Simapro 7.2 and Gabi 4.0	LCSA could be used for highlight the sustainability performance, especially, in this case, to know the amount of hazardous waste water and water used in the manufacturing process thus some improvements can be achieved.	-
111	(Wulf et al. 2018)	Electrolytic hydrogen production (*case study*)	Sustainable Development Goals as a Guideline for Indicator Selection in Life Cycle Sustainability Assessment	To select indicators based on overall goals and SDG indicators	Y	1 kg of hydrogen produced	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	-	-	PSILCA database	ADP, GWP, AP, EP, HT, POP	Levelized cost, net present value, profitability index, marginal cost	Association and bargaining rights, child labour, corruption, Drinking water coverage, education, fair salary	SDGs are tuned into LCSA indicators and then assigned to LCA, LCC and S-LCA	SDG goal-based indicators are more suitable to be applied in LCSA than SDG indicator based ones	SDGs focus on national level while LCSA are conducted on micro level. This created unjust justification
112	(Opher 2018)	Waste treatment (*case study*)	Comparative life cycle sustainability assessment of urban water reuse at various centralization scales	To compare sustainability performance of four different approaches of urban water reuse waste water treatment	Y	the annual supply, reclamation, and reuse of water consumed by a hypothetical city of 200,000 inhabitants	N	N	N	N	N	N	N	N	N	N	Y	N	Y	Y	Y	N	N	N	Local data for foreground processes and ecoinvent (v2.2) for background processes	Data from governmental institutions, engineering and civil works companies, and operators of wastewater treatment plants, manufacturers,	Interview and AHP analysis	ODP, HTP, PM, POP. Ionizing radiation, CC, ADP, land use, water resource, etc.	initial investment, operation and maintenance	Public (water saving, equity), Community (community engagement, local employment, urban landscape) Consumer (health	MCDA is conducted to weight sustainability criteria with judgement from 20 experts	Two alternatives have better sustainability performance in most impact categories	Weighting is problematic due to the subjectivity

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																										distributors, and service providers				concern, financecon venience)			
113	(Tarne 2018)	Automo-tive industry (*case study*)	Introducing weights to life cycle sustainability assessment how do decision-makers weight sustainability dimensions?	To apply a method to interpret multi-criteria assessment and emerging trade-offs to support sustainability decision-making	N	-	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Interview	Interview	Interview	GWP	Cost	Risk of social violation	Limit conjoint analysis is carried out to rank the the sustainability performance of a vehicle component.	All sustainability pillars were considered in an equal important	Sample size and geographical scope should be expanded. Weighting of indicators within sustainability dimensions and the drivers that influence personal decision-making in regard to weighting sustainability dimensions is needed.
114	(Martin 2018)	Bio-based product (*non-case study*)	Life Cycle Sustainability Evaluations of Bio-based Value Chains: Reviewing the Indicators from a Swedish Perspective	To identify the importance of sustainability indicators in LCSA, LCA, LCC and S-LCA studies on bio-based products	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	There is differing opinion between what the authors found to be important indicators with the indicators that are firmly used in studies, i.e. water depletion, indirect land use change, and impacts on ecosystem quality and biological diversity	-
115	(Koulou mpis & Azapagic 2018)	Electricity techno-logies (*case study*)	Integrated life cycle sustainability assessment using fuzzy inference: A novel FELICITA model	To apply fuzzy evaluation model called "FELICITA" in the integration of LCA, LCC and S-LCA of 5 electricity technologies	N	-	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Data are gathered from (Stamford & Azapagic 2012)			GWP, ODP, AP, EP, POCP	Capital cost, operating and maintenan-ce cost, fuel cost	Work injuries, accident fatalities, direct employ-ment	Fuzzy inference is used to facilitate assessing sustainability performance of different alternatives. Various methods are used, i.e. Triangular and Gaussian membership functions, different rule bases and defuzzification methods.	Overall LCSA indicator and ranking of alternatives are presented along with sensitivity analysis.	Challenge found are linked to the challenge of the fuzzy inference system in general, i.e. careful definition of the rule and membership function is needed.
116	(Mahbub et al. 2018)	Diesel additive (*case study*)	A life cycle sustainability assessment (LCSA) of oxymethylene ether (OME) as a diesel additive produced from forest biomass	To develop LCSA model for oxymethylene ether production	Y	1 MJ of heat produced from OME	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Most data gathered are secondary data from various sources.			GHG emissions, soot emission, water depletion	Capital cost, operational cost and total cost	Employ-ment potential, wage and benefits	LCA, LCC and S-LCA are performed with MCDA, alternative ranking method called PROMETHEE ans sensitivity analysis	Overall results show that forest residue pathway shows better sustainability performance than whole tree pathway	-
117	(Barros et al. 2018)	Truck tire (*case study*)	Propagating Uncertainty in Life Cycle Sustainability Assessment into Decision-Making Problems: A Multiple Criteria Decision Aid Approach	To perform LCSA with MCDA approach to rank the potential scenarios	Y	providing tires for truck transport with a payload of 32 metric tons over 600,000 km in Brazil in 2012 and managing used tires	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Not mentioned	Not mentioned	Databse from SHDB and interview with decision-makers	Environ-mental human health, ecosystem quality, resources	Economic life cycle cost	Labour rights and decent work, health and security, human rights, gover-nance	LCSA was performed followed by MCDA, uncertainty analysis and ranking analysis.MCDA models used are weighted sum, Prométhée II and Topsis. Two scenarios are applied; assessment with and without retreading	The LCSA performances for each indicator considered under two scenarios are presented	-

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118	(Gbededo et al. 2018)	Review article (*non case study*)	Towards a Life Cycle Sustainability Analysis : A systematic review of approaches to sustainable manufacturing	To review sustainable manufacturing methods and approaches to support LCSA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Literature review is carried out with structured approach that is systematic, transparent, methodical and reproducible.	Most approaches used in publications lack of holistic view.	Challenge found based on review is that aggregating and translating social aspects from qualitative to quantitative values and their influence on and interdependencies with other pillars of sustainability
119	(Zhou et al. 2019)	Waste managem ent (*case study*)	Model development of sustainability assessment from a life cycle perspective : A case study on waste management systems in China	To perform LCSA for comparing four waste management systems	Y	one t-MSW	N	N	N	N	N	N	Y	Y	Y	N	Y	N	N	N	N	Y	Y	Y	Site specific survey. Backgroun d data is from Gabi	Site specific survey and reports	Site specific survey and reports	GWP, AP, EP, POCP, FAETP, HTP and TETP	Investment cost, operating cost, decommissi oning cost, and projected revenue	Working conditions, Health and safety, Access to material resources, Delocalizat ion and migration, Public commitme nts to sustainabili ty issue, etc.	The assessment is conducted on four aspect: environment, energy, economic and society. LCA, LCC and S-LCA was performed with MCDM using AHP and entropy weight method. Sensitivity analysis was also performed	Incineration with fluidized bed furnace is better choice than incineration with moving grate furnace, landfill with and without energy recovery	-
120	(Tighnava rd et al. 2018)	Hybrid timber structure (*case study*)	Sustainability choice of different hybrid timber structure for low medium cost single-story residential building : Environmental , economic and social assessment	To assess sustainability performance of five different hybrid timber structure	Y	Whole structure scheme of single story residential building over 50 years of its life span	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	Y	N	N	N	Y	Y	N	Various sources (i.e. Malaysia Life Cycle Inventory Database)	Malaysian Statistic Databases	Site interview with different stake-holders	GWP, HTP, EP, FDP, AP	Cost, present value	Wage, job creation	LCA, LCC and S-LCA was performed to five types of timber structure from cradle to grave. Sensitivity analysis was also carried out on electricity usage	LCA results of five types of timber structure are presented along with contribution analysis in five categories in each type of timber. LCC and S-LCA (salary status and job creation are also presented)	-
121	(Hannouf & Assefa 2018)	Methodo-logical article (*non-case study*)	A Life Cycle Sustainability Assessment-Based Decision-Analysis Framework	To propose LCSA-based decision making framework	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	To make decision and avoid trade-offs based on LCSA results, the authors propose five steps: problem definition, objective identification, potential sustainability solutions' generation, evaluation of potential sustainability solutions and trade-off analysis	Many but overall result is to show the interrelationships between the interdisciplinary LCSA and propose sustainability improvements	Finding potential yet specific solutions is challenging. To solve it, the authors propose to use primary data and perform uncertainty analysis.
122	(Wang et al. 2018)	Waste manage-ment (*case study*)	Development of an Ex-Ante Sustainability Assessment Methodology for Municipal Solid Waste Management Innovations	To assess sustainability performance of municipal solid waste management of Bandung city based on LCSA and SDGs	Y	the amount of MSWM generated in Bandung City per year	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Data are collected from many sources, i.e. site-specific study, local MSWM sector statistics, local academic research, international statistics on waste (World Bank and Waste Atlas), expert consultation, stakeholder interview, etc.			Climate, Terrestrial ecosystem, Aquatic system, Abiotic resource depletion	Poverty, energy supply and efficiency, job and employment	Health, education & skill develop-ment, egalitarian society	SDGs are used as macro goal identification. Gabi was used for LCA. S-LCA was done mostly by quantitative data and interview	The results are presented by score of impact (-1 to +1) for each category.	Main challenge is regarding to equal-weighting of life cycle phases that cause problematic issue of overinterpretation or underinterpretation of the impact

#	Artic-les	Area	Title	Goal	Functional Unit		The scope considered																		Life cycle inventory analysis (data collection sources)			Life cycle impact assessment			Methodology	Main results	Challenges
							Extraction			Produc-tion			Transpor-tation			Construc-tion/ Manufac-turing			Use/ Opera-tion			End-of-Life											
							Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc	Env	Eco	Soc			
123	(Ren 2018)	Electricity genera-tion (*non-case study*)	Life cycle aggregated sustainability index for the prioritization of industrial systems under data uncertainties	To develop and enhance method to measure and prioritize sustainability of industrial systems under uncertainties	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Main data are collected from the work of Stamford and Azapagic (2012)			GWP, ODP, PO, AP, HT	Rate of return, net present value	Health and safety, social acceptability and benefits	Method to rank sustainability performance of four electricity generations in UK is performed.	Results show comparison matrices determining the weights of the three pillars of sustainability and the local and global weights of the criteria.	-
124	(Millward-hopkins et al. 2018)	Waste recovery (*case study*)	Fully integrated modelling for sustainability assessment of resource recovery from waste	To develop multidimensional model for assessing social, environmental, technical and economic aspect of resource recovery systems	N	-	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	From various sources (i.e. UK Databases)	From various sources	From various sources (i.e. from landfilling site)	Embodied carbon emissions, ODP, HTP	Prices, wages	Working hours, noise pollution, social acceptance	LCA is integrated with MFA to evaluate s environmental, social, economic and technical do- mains	The results of illustrative case study are shown according to scenarios applied (i.e. carbon emissions (both in the low-and high-carbon cases); total fatalities (in the domestic production and imported ash scenarios); and UK profits aggregated over the EP, CCI, and disposal sectors)	Intensive data are required. Uncertainty analysis needs to be performed for future study. How to value fixed capital (i.e. long plan, infrastructure), to choose proper matrics, to integrate results across aspect are also main challenges.

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