Supplementary Material

Table S2. Articles included after the full-text screening

Nr.	Authors	Year	Title	Source title	Abstract	Keywords	DOI
1	Crovella, Tiziana and Paiano, Annarita and Falciglia, Pietro Paolo and Lagioia, Giovanni and Ingrao, Carlo	2024	Wastewater recovery for sustainable agricultural systems in the circular economy - A systematic literature review of Life Cycle Assessments	SCIENCE OF THE TOTAL ENVIRONMENT	Water availability and quality are known to affect agricultural production and nutrition. The aim of this study was to elaborate a systematic literature review of the most sustainable ways of wastewater treatment towards achieving circular economy (CE) in agro-industry activities. From the SLR, the authors selected twenty-seven papers that they classified into the three research themes of recovery of wastewater into irrigation water, extraction of sludge for production of bio-based compounds, and recovery of nutrients for soil amendment, including recovering of feeds for aquaculture, and recovery of nutrient biosolids for soil amendment. Results underlined that the recovery of nutrients biosolids for soil amendment can generate a GWP gain up to - 37 kg CO2-eq. So, the review highlighted that wastewater recovery for multiple purposes can be truly effective for the environmental sustainability of agricultural systems, and that LCA is a valid tool to assess and improve that sustainability. Under this perspective, this SLR's findings can stimulate public administrations at national and local scales in their planning and funding activities towards implementing circular bioeconomy paths based upon wastewater recovery for a sustainable, resilient agriculture. Overall, the authors believe that their article was effective in overviewing the current wastewater recovery paths in the CE context, and in highlighting key methodological aspects and findings of the reviewed LCAs, to advance the specialised literature and knowledge, and to guide practitioners for future LCA applications in the field. Finally, through its main findings, the article effectively contributes to the whole research project which it is part of and which the authors are deeply involved in. That research is performed under the Progetto GRINS "Growing Resilient, Inclusive and Sustainable" thanks to a PNRR M4C2-Investment 1.3 - GRINS with the aim of "Building a dataset for the circular economy of the main Italian production systems". PU - ELSEVIER PI - AMSTERDAM PA - RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS		10.1016/j.scitotenv.2023.169310
2	Ghosh, Tapajyoti and Uekert, Taylor and Walzberg, Julien and Carpenter, Alberta C.	2024	Comparing Parallel Plastic-to-X Pathways and Their Role in a Circular Economy for PET Bottles	ADVANCED SUSTAINABLE SYSTEMS	The United States generates the most plastic waste of any country and is a top contributor to global plastic pollution. Multiple end-of-life strategies must be implemented to minimize environmental impacts and retain valuable plastic material, but it is challenging to compare options that generate products with different lifetimes and utilities. Herein, they present a material flow model equipped with consequential life cycle assessment, cost analysis, and a plastic circularity indicator that considers product quality and lifetime. The model is used to estimate the greenhouse gas (GHG) emissions, circularity, and cost of polyethylene terephthalate (PET) bottle mechanical downcycling to lower-quality resin, closed-loop glycolysis to food-grade PET, upcycling to glass fiber-reinforced plastic, and conversion to non-plastic products (electricity, oil) on a United States economy-wide basis for the year 2020. A brute force algorithm		10.1002/adsu.202300068

					suggests that a combination of 68% glycolysis, 11% mechanical recycling, 6% upcycling, 9% landfilling, and 5% incineration can minimize the cost and GHG emissions and maximize the circularity of the current PET economy. However, uncertainty around transportation distances, materials recovery facility efficiencies, and recycling yields can result in different "optimal" pathway mixes. This flexible framework enables informed decision-making to move toward a cost- and environment-conscious circular economy for plastic. PU - WILEY-V C H VERLAG GMBH PI - WEINHEIM PA - POSTFACH 101161, 69451 WEINHEIM, GERMANY	
3	Lopez-Sanchez, Anaid and Garcia-Lopez, Carlos Daniel and Lara-Topete, Gary Ossmar and Castanier-Rivas, Juan Daniel and Barajas-Alvarez, Paloma and Gonzalez-Lopez, Martin Esteban and Silva-Galvez, Ana Laura and Zhou, Hongying and Lan, Christopher Q. and Robles-Rodriguez, Carlos Eduardo and Meramo-Hurtado, Samir and Gradilla-Hernandez, Misael Sebastian	2025	Consequential life cycle assessment of pretreatment strategies for a microalgae-based wastewater treatment pilot unit in a circular livestock industry bioeconomy	ALGAL RESEARCH-BIOMASS BIOFUELS AND BIOPRODUCTS	This study presents a Consequential Life Cycle Assessment (CLCA) of a microalgae-based wastewater treatment system for the livestock industry, integrated with a circular bioeconomy approach through biofertilizer production and biogas generation through anaerobic digestion (AD). Three treatment scenarios were evaluated, each employing different combinations of pretreatment technologies, including bioflocculation with chitosan. A scaled-up process model was developed using SuperPro Designer, and the environmental performance was assessed using SimaPro 9.7. Results indicate that scenario with a previous pretreatment using a centrifugation and UV radiation achieved the lowest global warming potential (8129 kg CO2-eq per ton of dried microalgae), reduced fine particulate matter emissions (38.55 kg PM2.5-eq), and required less water consumption (114.29 m3) due to minimal chitosan usage compared to the other scenarios. Sensitivity analysis revealed significant variations in environmental impacts based on microalgae yield and biofertilizer application rates. A 20 % increase in biofertilizer application led to a 27.68 % additional reduction in global warming potential. This research provides compelling evidence for the environmental feasibility and economic viability of large-scale microalgaebased wastewater treatment systems, offering a promising pathway towards sustainable livestock practices and a circular bioeconomy within the agricultural sector. PU - ELSEVIER PI - AMSTERDAM PA - RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS	10.1016/j.algal.2025.104041
4	Cobo, Selene and Dominguez-Ramos, Antonio and	2018	Trade-Offs between Nutrient Circularity and	ENVIRONMENTAL SCIENCE & TECHNOLOGY	Measuring the circularity of resources is essential to assessing the performance of a circular economy. This work aims at proposing an indicator that quantifies how effective a system is at extending the lifetime of its waste components after they have been discarded. The developed indicator was applied to study the circularity of nutrients within a system that handles the organic waste (OW) generated in the Spanish region of Cantabria. A superstructure was developed to determine the	10.1021/acs.est.8b01590

	Irabien, Angel		Environmental Impacts in the Management of Organic Waste		optimal configuration of the system. It is composed of alternative unit processes for (1) the management of OW and (2) the application of the recovered products as soil amendment to grow corn. A multiobjective mixed integer linear programming problem was formulated under two policy scenarios with different source separation rates. The problem was optimized according to six objective functions: the circularity indicators of carbon, nitrogen, and phosphorus, which are maximized, and their associated environmental impacts to be minimized (global warming, marine eutrophication, and freshwater eutrophication). The model was fed with the life cycle assessment results obtained with the Environmental Assessment System for Environmental TECHnologies (EASETECH) version 2.3.6 and the nutrient flows in the agriculture subsystem, which were calculated with Denitrification-Decomposition (DNDC) version 9.5. It was concluded that improving nutrient circularity paradoxically leads to eutrophication impacts and that increasing the SSR of OW has a positive effect on the carbon footprint of the system. PU - AMER CHEMICAL SOC PI - WASHINGTON PA - 1155 16TH ST, NW, WASHINGTON, DC 20036 USA	
5	Rufi-Salis, Marti and Petit-Boix, Anna and Leipold, Sina and Villalba, Gara and Rieradevall, Joan and Moline, Eduard and Gabarrell, Xavier and Carrera, Julian and Suarez-Ojeda, Maria Eugenia	2022	Increasing resource circularity in wastewater treatment: Environmental implications of technological upgrades	SCIENCE OF THE TOTAL ENVIRONMENT	A paradigm shift is needed in wastewater treatment plants (WWTPs) to progress from traditional pollutant removal to resource recovery. However, whether this transformation produces overall environmental benefits will depend on the efficient and sustainable use of resources by emerging technologies. Given that many of these technologies are still being tested at the pilot scale, there is a lack of environmental assessments quantifying their impacts and benefits. In particular, an integrated approach to energy and nutrient recovery can elucidate the potential configurations for WWTPs. In this study, we conduct a life cycle assessment (LCA) of emergent wastewater treatment technologies aimed at increasing resource circularity in WWTPs. We focus on increasing energy self-sufficiency through biogas upgrades and a more radical circular approach aimed at nutrient recovery. Based on a case-study WWTP, we compare its current configuration with (1) implementing autotrophic nitrogen removal in the mainstream and deriving most of the organic matter for biogas production, which increases the quality and quantity of biogas available for energy production; (2) implementing struvite recovery through enhanced biological phosphorus removal (EBPR) as a radical approach to phosphorus management, offering an alternative to mineral fertilizer; and (3) a combination of both approaches. The results show that incremental changes in biogas production are insufficient for compensating for the environmental investment in infrastructure, although autotrophic nitrogen removal is beneficial for increasing the quality of the effluent. Combined phosphorus and energy recovery reduce the environmental impacts from the avoided use of fertilizers and phosphorus and the nitrogen release into water bodies. An integrated approach to resource management in WWTPs is thus desirable and creates new opportunities toward the implementation of circular strategies with low environmental impact in cities. PU - ELSEVIER PI - AMSTERDAM PA - RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS	10.1016/j.scitotenv.2022.156422
6	Islam, Nazmul and Hall, Murray R. and MacMillan, Colleen and Gordon, Stuart	2026	Life cycle assessment and the emergence of product circularity: A review with context	ENVIRONMENTAL IMPACT ASSESSMENT REVIEW	Life Cycle Assessment (LCA) evaluates the environmental impacts of products, processes, and services throughout their life cycles, from resource extraction to disposal. Governed by International Organization for Standardization (ISO) standards 14,040 and 14,044, LCA includes a Life Cycle Inventory (LCI) to collect data on materials, energy, water use, and emissions, and a Life Cycle Impact Assessment (LCIA) to quantify environmental impacts like climate change, biodiversity loss, waste, and pollution. The growing scale of consumption and waste generation over the past two decades has made these impacts increasingly significant for the global textile industry. This is particularly so in Australia, which now surpasses the USA in terms of textile consumption per capita. A move from linear production, processing, consumption, and disposal models to longer use and circular approaches, where the material properties of the textile are retained or	10.1016/j.eiar.2025.108198

			to the textile supply chain in Australia		reused, is both logical and commendable. However, practical implementation is fraught with challenges. Large logistical and technical hurdles arise in reconfiguring supply chains to facilitate the return, (re)classification, and recycling of products. In this paper, textile sector-related frameworks and standards are reviewed for their alignment with circular economy (CE) principles and support of relevant United Nations Sustainable Development Goals (SDGs). Gaps in current LCA and LCIA frameworks, particularly about system boundaries and localized impact assessments, are noted along with details of how these can be adapted to support the textile sector's embrace of CE principles. Reflecting these deficiencies, a review of sustainability reports from major Australian clothing brands reveals that most companies provide quantitative future targets and annual mitigated values for Scope 1, 2, and 3 greenhouse gas (GHG) emissions, as well as short-term and long-term decarbonization targets. It also revealed significant gaps in sustainability and circularity initiatives reporting, such as reductions of virgin fibre use, microfibre shedding, and supporting circular business models like the resale of used products. Expanding LCA boundaries and impact assessments will be essential to properly steward and measure the environmental benefits of circular textile production systems and behaviours, and to help avoid the growing repercussions of the current market behaviour. PU - ELSEVIER SCIENCE INC PI - NEW YORK PA - STE 800, 230 PARK AVE, NEW YORK, NY 10169 USA	
7	Zhang, Cheng-Yao and Nakatani, Jun and Yu, Biying and Wei, Yi-Ming	2026	Quantifying the carbon circularity, climate and energy benefits of plastic recycling through circular flow analysis: Application to plastic packaging waste in Japan	RESOURCES CONSERVATION AND RECYCLING	Carbon circularity has attracted increasing attention alongside climate change impacts and fossil energy consumption in plastic recycling evaluations. Herein, we introduce the carbon flow and circular diagram (CFCD) method, a unified framework designed to assess plastic recycling by integrating carbon circularity, carbon neutrality, and fossil energy independence. CFCD visualizes carbon flows by mapping carbon inputs and outputs across various pathways. We apply our approach to the complex ecosystem of plastic packaging waste recycling in Japan. Our findings reveal that catalytic cracking preserves 56.8 % of carbon circularity, whereas mechanical recycling achieves moderate carbon circularity and climate benefit. High-efficient energy recovery delivers substantial climate and energy benefits with poor circularity. Gasification for ammonia production yields the highest energy benefit of 57.9 MJ/kg of waste yet is largely ineffective in improving carbon circularity, whereas the carbon capture and utilization emerges as a key strategy. PU - ELSEVIER PI - AMSTERDAM PA - RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS	10.1016/j.resconrec.2025.108549
8	Aleisa, Esra and Alsulaili, Abdalrahman and Almuzaini, Yasmeen	2021	Recirculating treated sewage sludge for agricultural use: Life cycle assessment for a circular economy	WASTE MANAGEMENT	The objective of this study is to assess the environmental value of recirculating nutrients from treated sewage sludge by application to agricultural soils to grow forage as opposed to landfilling and incineration. The methodological choices are aligned to the circular economy framework using life cycle assessment. Consequential modeling and open loop modeling were adopted and adhere to ISO 14044 and International Reference Life Cycle Data System (ILCD) standards. The functional unit is defined in terms of the amounts of nitrogen (N), phosphorus (P) and potassium (K) recirculated from the treated sewage sludge produced annually in Kuwait. The results indicate a reduction in environmental burden with respect to fossil fuel depletion, metal depletion and climate change. A total of 95% of the reduction is realized by avoiding virgin nitrogen production and instead using its recirculated counterpart. Considerable amounts of natural gas, coal, dinitrogen monoxide (nitrous oxide, N2O) and copper are consumed during virgin N fertilizer production. PU - PERGAMON-ELSEVIER SCIENCE LTD PI - OXFORD	10.1016/j.wasman.2021.08.035

					PA - THE BOULEVARD, LANGFORD LANE, KIDLINGTON, OXFORD OX5 1GB, ENGLAND	
9	Briassoulis, Demetres and Pikasi, Anastasia and Hiskakis, Miltiadis	2021	Organic recycling of post-consumer /industrial bio-based plastics through industrial aerobic composting and anaerobic digestion - Techno-economic sustainability criteria and indicators	POLYMER DEGRADATION AND STABILITY	The sustainability assessment of alternative EoL routes for the post-consumer/industrial bio-based plastics should ensure that these waste streams are routed to the optimal options that would allow, as a first priority, for their recirculation as valuable secondary bio-based resources, in support of the circular bioeconomy. Organic recycling, is considered as the second preferred alternative End-of-Life (EoL) option, for post-consumer/industrial biodegradable bio-based plastics that are characterised as mechanically/chemically non-recyclable. Techno-economic sustainability criteria and indicators are proposed based on an extended literature review to assure the technical feasibility and economic viability of organic recycling for these products. The proposed TESA methodology for organic recycling is organised into 3 integrated TESA Criteria: a) "Technical feasibility"; b) "Economic viability"; c) "Common technoeconomic - environmental" criteria, including TESA criteria that are used also as environmental sustainability assessment criteria through LCA. The recirculation potential TESA criterion has a much lower importance for organic recycling as compared to material recovery. A set of indicators, evaluated by relevant metrics, are proposed for the assessment of the corresponding techno-economic criteria. The overall assessment of the organic recycling options for bio-based biodegradable plastics, requires a parallel assessment based also on environmental and social sustainability criteria. These criteria are beyond the scope of the present work. (C) 2021 Elsevier Ltd. All rights reserved. PU - ELSEVIER SCI LTD PI - London PA - 125 London Wall, London, ENGLAND	10.1016/j.polymdegradstab.2021.109642
10	Zhu, Xiefei and Labianca, Claudia and He, Mingjing and Luo, Zejun and Wu, Chunfei and You, Siming and Tsang, Daniel C. W.	2022	Life-cycle assessment of pyrolysis processes for sustainable production of biochar from agro-residues	BIORESOURCE TECHNOLOGY	Net carbon management of agro-residues has been an important pathway for reducing the environmental burdens of agricultural production. Converting agro-residues into biochar through pyrolysis is a prominent management strategy for achieving carbon neutrality in a circular economy, meeting both environmental and social concerns. Based on the latest studies, this study critically analyzes the life cycle assessment (LCA) of biochar production from different agro-residues and compares typical technologies for biochar production. Although a direct comparison of results is not always feasible due to different functional units and system boundaries, the net carbon sequestration potential of biochar technology is remarkably promising. By pyrolyzing agro-residues, biochar can be effectively produced and customized as: (i) alternative energy source, (ii) soil amendment, and (iii) activated carbon substitution. The combination of life cycle assessment and circular economy modelling is encouraged to achieve greener and sustainable biochar production. PU - ELSEVIER SCI LTD PI - London PA - 125 London Wall, London, ENGLAND	10.1016/j.biortech.2022.127601
11	Mancuso, Giuseppe and Habchi, Sanae and Maraldi, Mirko and Valenti, Francesca and El Bari, Hassan	2024	Comprehensive review of technologies for separate digestate treatment and agricultural valorisation within circular and green economy	BIORESOURCE TECHNOLOGY	Anaerobic digestion (AD) has the potential to catalyse the shift from a linear to a circular economy. However, effective treatment and management of both solid (DSF) and liquid (DLF) digestate fraction treatment and management require adopting sustainable technologies to recover valuable by-products like energy, biofuels, biochar, and nutrients. This study reviews state-of-the-art advanced technologies for DSF and DLF treatment and valorisation, using life cycle assessment (LCA) and techno-economic analysis (TEA) in integrated digestate management (IDM). Key findings highlight these technologies' potential in mitigating environmental impacts from digestate management, but there's a need to improve process efficiency, especially at larger scales. Future research should prioritize cost-effective and eco-friendly IDM technologies. This review emphasizes how LCA and TEA can guide decision-making and promote sustainable agricultural practices. Ultimately, sustainable IDM technologies can boost resource recovery and advance circular economy principles, enhancing the environmental and economic sustainability of AD processes. PU - ELSEVIER SCI LTD PI - London PA - 125 London Wall, London, ENGLAND	10.1016/j.biortech.2024.131252

12	Badran, S. and Massoud, M. A. and Stephan, R. and Elbassuoni, S. and Chalak, A. and Abiad, M. G.	2025	Opportunities for circular economy in waste reuse: Insights from social media data mining	RESOURCES CONSERVATION AND RECYCLING	Transitioning to circular economy requires robust waste management to minimize waste, maximize resource use, and promote recycling and reuse. This study examines reuse as a primary waste prevention strategy within this framework. It identifies commonly reused items and assesses the environmental benefits of online second-hand shops versus disposal or purchasing new items. AI methodologies, including information retrieval and machine learning, analyzed over 1000 images from Lebanese Instagram thrift shops to train a classifier. Environmental impacts were quantified using LCA studies. Results show textiles, clothing, and shoes are the most reused items. Online thrift shops offer affordable, sustainable clothing, reducing the need for new production. Most reused items were in good condition, indicating they can replace new ones, conserving resources. Reuse outperforms recycling, though furniture and electronics have lower reuse rates. AI's potential in waste management and the importance of sustainable reuse practices are highlighted, suggesting significant efficiency and cost improvements. PU - ELSEVIER PI - AMSTERDAM PA - RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS	10.1016/j.resconrec.2024.108100
13	Heriyanto and Ghose, Anirban and Hossain, Rumana and Sahajwalla, Veena	2025	Novel upcycling of mixed textile waste into valuable activated carbon: A circular economy solution	RESOURCES CONSERVATION AND RECYCLING	The escalating volume of post-consumer textile waste necessitates innovative upcycling strategies that extend beyond conventional recycling practices. This study presents a scalable approach for converting mixed postconsumer textile waste-with minimal sorting-into high-surface-area activated carbon (500-2300 m2/g), thereby addressing a critical environmental and waste management challenge. In parallel, the work seeks to enable precise control over pore architecture through systematic variation of key activation parameters, including activation temperature, impregnation ratio, and processing steps, enabling the production of application-specific porous adsorbents. A one-step H3PO4 activation at 800 degrees C with a 1:1 impregnation ratio yielded a well-balanced micropore-mesopore network with an average distribution of 30:70, suitable for the adsorption of organic pollutants and large molecular species. In contrast, a two-step activation process or a lower activation temperature (700 degrees C) favoured microporous structures, with micro-to-meso ratios of 80:20 and 70:30, respectively, optimizing the uptake of smaller contaminants. A comparative Life Cycle Assessment (LCA) confirmed the environmental advantages of the developed process, demonstrating a 36 % reduction in embodied carbon and over 99 % reduction in embodied energy demand relative to conventional coal-derived activated carbon. Improvements were also observed in secondary impact categories, including acidification, smog formation, and respiratory health effects. These results underscore the dual benefits of diverting mixed textile waste from landfill while producing low-impact, high-performance porous materials for next-generation adsorption technologies, supporting the advancement of circular economy principles. PU - ELSEVIER PI - AMSTERDAM PA - RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS	10.1016/j.resconrec.2025.108526
14	Mayor, Alvaro and Vinardell, Sergi and Ganesan, Kishore and Bacardi, Carles and Cortina, Jose Luis and Valderrama, Cesar	2023	Life-cycle assessment and techno-economic evaluation of the value chain in nutrient recovery from wastewat	SCIENCE OF THE TOTAL ENVIRONMENT	The recovery of nitrogen and phosphorus is important to promote circular economy in wastewater treatment plants (WWTPs). In this study, the life cycle assessment (LCA) and techno-economic assessment (TEA) of a novel pilotscale plant aimed at recovering ammonium nitrate and struvite for subsequent application in agriculture was conducted. The nutrient recovery scheme was implemented in the sludge line of the WWTP and included (i) struvite crystallisation and (ii) ion-exchange process combined with gas permeable membrane contactor. The LCA showed that using a fertilizer solution containing the recovered nutrients was environmentally better in most of the impact categories evaluated. Ammonium nitrate was the most important environmental contributor when using the recovered fertilizer solution as a result of the high consumption of chemicals needed for its production. The TEA illustrated that the implementation of the nutrient recovery scheme in the WWTP featured a negative net present value (NPV), primarily attributed to the high consumption of chemicals (representing 30	10.1016/j.scitotenv.2023.164452

			er treatment plants for agricultural application		% of the gross cost). However, the implementation of the nutrient recovery scheme in the WWTP could be economically favourable if the cost of ammonium nitrate and struvite increased to 0.68 and 0.58 euro/kg, respectively. The results of this pilot-scale study highlight that nutrient recovery considering the whole value chain for fertilizer application can be an attractive full-scale alternative from a sustainability point of view. PU - ELSEVIER PI - AMSTERDAM PA - RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS	
15	Arashiro, Larissa T. and Josa, Irene and Ferrer, Ivet and Van Hulle, Stijn W. H. and Rousseau, Diederik P. L. and Garfi, Marianna	2022	Life cycle assessment of microalgae systems for wastewater treatment and bioproducts recovery: Natural pigments, biofertilizer and biogas	SCIENCE OF THE TOTAL ENVIRONMENT	The aim of this study was to assess the potential environmental impacts associated with microalgae systems for waste-water treatment and bioproducts recovery. In this sense, a Life Cycle Assessment was carried out evaluating two sys-tems treating i) urban wastewater and ii) industrial wastewater (from a food industry), with the recovery of bioproducts (i.e. natural pigments and biofertilizer) and bioenergy (i.e. biogas). Additionally, both alternatives were compared to iii) a conventional system using a standard growth medium for microalgae cultivation in order to show the potential benefits of using wastewater compared to typical cultivation approaches. The results indicated that the system treating industrial wastewater with unialgal culture had lower environmental impacts than the system treating urban wastewater with mixed cultures. Bioproducts recovery from microalgae wastewater treatment systems can re-duce the environmental impacts up to 5 times compared to a conventional system using a standard growth medium. This was mainly due to the lower chemicals consumption for microalgae cultivation. Food-industry effluent showed to be the most promising scenario for bioproducts recovery from microalgae treating wastewater, because of its better quality compared to urban wastewater which also allows the cultivation of a single microalgae species. In conclusion, microalgae wastewater treatment systems are a promising solution not only for wastewater treatment but also to boost the circular bioeconomy in the water sector through microalgae-based product recovery. PU - ELSEVIER PI - AMSTERDAM PA - RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS	10.1016/j.scitotenv.2022.157615
16	Vera, Ramon E. and Vivas, Keren A. and Forfora, Naycari and Marquez, Ronald and Urdaneta, Isabel and Frazier, Ryen and de Assis, Camilla Abbati and de Assis, Tiago and Treasure, Trevor and Farrell, Matthew and Ankeny, Mary and Saloni, Daniel and Pal,	2024	From waste to advanced resource: Techno-economic and life cycle assessment behind the integration of polyester recycling and glucose production to valorize fast fashion garments	CHEMICAL ENGINEERING JOURNAL	This work demonstrates the technical, economic, and environmental viability of integrating enzymatic hydrolysis, mechanical refining, and total chlorine-free (TCF) bleaching processes for industrial-scale production of glucose from textile waste. The process features an innovative mechanical refining pretreatment coupled with TCF oxidation of dyes to achieve over 90% improvement in enzymatic hydrolysis yields of cotton textile waste while also promoting the purification and recycling of synthetic fibers. A comprehensive techno-economic analysis was performed based on a 14,000 bone dry tons (BD tons) annual glucose production line, utilizing both 100% cotton and cotton/polyester blends, which reveals capital investments ranging from USD 5.6 to 7.9 million, with manufacturing costs per ton of glucose varying between USD 215 and USD 475, depending on the textile blend used. The cotton/polyester 50/50 blend scenario had the lowest minimum selling price (USD 290 per ton of glucose) due to the revenue from the unhydrolyzed synthetic fibers, which are a valuable and key coproduct. A sensitivity analysis highlights the significant influence of recycled polyester content and market prices on the economics. Additionally, a life cycle assessment was performed to compare the carbon footprint of the four scenarios. In contrast to other existing pretreatments that can contribute to up to 70% of the emissions in enzymatic hydrolysis of textiles, the mechanical refining pretreatment can contribute as low as 10% of the total emissions in the process proposed in this work. Even when certain challenges remain, such as the development of a robust supply chain model, the conversion pathway shown in this work for upcycling cotton textile waste into value-added chemicals represents a promising opportunity to combat textile landfilling and foster the circular economy within the industry. PU - ELSEVIER SCIENCE SA PI - LAUSANNE PA - PO BOX 564, 1001 LAUSANNE, SWITZERLAND	10.1016/j.cej.2024.156895

	Lokendra and Jameel, Hasan and Gonzalez, Ronalds						
17	van Zelm, Rosalie and Seroa da Motta, Raquel de Paiva and Lam, Wan Yee and Menkveld, Wilbert and Broeders, Eddie	2020	Life cycle assessment of side stream removal and recovery of nitrogen from wastewater treatment plants	JOURNAL OF INDUSTRIAL ECOLOGY	In the light of a circular economy, the Nijhuis Ammonia Recovery system (AECO-NAR) was developed to not only remove nitrogen from wastewater streams, but also produce ammonium sulfate (AS), used as fertilizer, in a single plant. The goal of this paper was to quantify the environmental impacts of side stream ammonia recovery with the AECO-NAR system and compares them with the impacts of side stream nitrogen removal combined SHARON (partly nitrification)-anammox plant. For this, an environmental life cycle assessment was performed with a functional unit (FU) of the treatment of 1 kg of total dissolved nitrogen inflow. Since AS obtained by the AECO-NAR is a by-product of the ammonia removal process, allocation was based on system expansion. Foreground inventory data were obtained from a full-scale plant. ReCiPe2016 was used to determine human health and biodiversity impacts. Results show that due to the production of AS in an integrated water treatment and production system, the AECO-NAR avoids impacts of current AS production, leading to negative impact scores. Impacts per FU decrease with increasing inflow concentrations of ammonia. Main improvement options are the use of renewable energy and the replacement of the cleaning chemical citric acid with a sustainable alternative. Total impacts of the AECO-NAR system diminish when comparing the system to the biological SHARON-Anammox system, due to production of AS fertilizer product. Due to the fertilizer production step being integrated in the side stream treatment, the complete system is beneficial over ammonia recovery and wastewater treatment as separate systems. PU - WILEY PI - HOBOKEN PA - 111 RIVER ST, HOBOKEN 07030-5774, NJ USA		10.1111/jiec.12993
18	Liu, Ying and Zheng, Zhiyuan and Zhao, Lu and Wang, Zhen	2021	Quality assessment of post-consumer plastic bottles with joint entropy method: A case study in Beijing, China	RESOURCES CONSERVATION AND RECYCLING	Recycling of plastic bottles is a fundamental strategy to reduce the need of fossil resources and protect global environments. The collection of post-consumer plastic bottles (PCPBs) is a key node of the recycling of plastics due to its influences on the subsequent life cycle stages. However, there is still a lack of quantitative assessment on the quality of PCPBs, especially considering the contamination and the mixture of different plastics in the collection stage. This study provides an indicator based on the joint entropy method to evaluate the quality of PCPBs in collection stage, which includes components, polymer types and colors three levels. This indicator (Quality-value) is applied to evaluate the quality of PCPBs' collection system in Beijing city, China, which is based on an on-site survey including 27 samples gathered from 4 distribution centers and 5 collection sites. The results showed that the quality of PCPBs decreased through the collection system of Beijing, which degraded from post-consumer bottles (0.320<Q<0.325) to pre-production bottles (0.311 <Q <0.312). The type of residential area is identified as a key factor of the PCPBs' quality in collection sites. There is no obvious difference between formal and informal business models in the surveyed area. Providing three levels of quality equally weighted, colors sorting had the greatest potential to improve the quality of PCPBs compared to components and polymers sorting. We suggest that joint-entropy based quality assessment can help to manage waste collection system in an efficient way to meet the need of circular economy. PU - ELSEVIER PI - AMSTERDAM PA - RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS		10.1016/j.resconrec.2021.105839
19	Teixeira, M.M. and Rodrigues Pinto, L.F. and Arns,	2025	Advantages of natural polymer yarn	Cleaner Engineering and Technology	Ensuring transparency in textile production, particularly in addressing environmental and social issues, has driven the development of technologies such as smart tags, encrypted labels, blockchain, and fibre DNA. However, full traceability from raw material extraction to the finished product remains a challenge, especially due to chemically aggressive processes like dyeing and	Circular economy;Industry 4.0;Sustainability;Textile industry;Traceability;Circular economy;Codes (symbols);Economic	10.1016/j.clet.2025.101121

	V.D. and Ernesto, A.D.S. and Oliveira Neto, G.C.D. and Amorim, M. and Facchini, F.		encoding technology for traceability in the textile industry		washing. This study adopted a case study approach to evaluate a yarn tracking technology that embeds a code directly into the textile product, remaining functional throughout its life cycle. The assessment combined technical tests, payback-based economic analysis, and environmental evaluation using the Mass Intensity Total (MIT) metric. Conducted in a Brazilian textile company, the study validated the coding system's durability and feasibility. The code remained readable after industrial processing, enabling traceability across all process stages. Results revealed annual cost saving of USD 5639.00 and a payback period of approximately 5.4 years. The implementation also led to a reduction of 8.5 million kilograms in MIT, indicating substantial environmental benefits. The system facilitates the identification of leftover fabric cuts, supporting waste reduction and material conservation. Additionally, by geolocating production steps, it helps monitor working conditions and mitigate risks of labour analogous to slavery. By ensuring durable, embedded traceability, this research advances biopolymer tracking and contributes to more transparent, circular, and socially responsible practices in the textile sector. The adoption of this technology may assist companies in aligning operations with transparency goals, legal compliance, and sustainability standards. © 2025 The Authors	analysis;Environmental technology;Industrial economics;Life cycle;Regulatory compliance;Social aspects;Textile finishing;Textiles;Transparency;Wool;Yarn;Block-chain;Encoding technology;Environmental issues;Finished products;Raw material extraction;Smart tags;Social issues;Textile production;Traceability;Sustainable development;Textile industry	
20	Khan, M. and Nizami, A.-S. and Yasar, A. and Musharavati, F.	2025	Advancing vertical integration and circularity in the textile industry by developing a novel framework of textile sustainability index	Sustainable Futures	As the world population grows, the demand for essential goods, such as clothing and textiles, naturally increases. The textile industry is the backbone of Pakistan's export sector. The textile industry must prioritize sustainability on a large scale to meet the demands of international buyers and ensure the exportability of its products. This study aims to develop the Textile Sustainability Index (TSI), which helps industrialists evaluate the sustainability performance of their textile firms against established standards or benchmarks. The sustainability assessment was done using the proximity to target method. This method measures the industry's sustainability performance in relation to the standards and targets established by the industry. The closer the industry's performance aligns with the targets, the better the compliance with industry benchmarks. Firstly, the indicator performance scores for each parameter were calculated, and then these scores were aggregated into parameter scores for each category. Afterwards, the parameter scores were combined to determine the aspect scores for environmental, economic, and social factors. Lastly, the aspect scores were compiled to calculate the textile sustainability index score. The textile firm's vertical integration process has been selected and used as a case study to validate the applicability of this index. The sustainability performance of the selected firm was evaluated, and the overall TSI of the firm was calculated to be 91.72, comprising environmental (36.91 %), economic (33.66 %), and social (21.15 %) components. Low-performance indicators and parameters were identified based on this TSI. The results indicated that parameters of water consumption, diesel consumption, and chemical consumption were identified as hotspot areas in environmental aspects, and practical improvements were suggested to optimize the process. From an economic perspective, the efficiency of raw material input and the profitability of finished products require improvement. In social aspects, only the risk factor parameter is required for advancement to achieve sustainable targets. This research presents a framework for measuring the sustainability of textile industries, encompassing environmental, economic, and social performance. Thus, this research can be valuable to industrialists, policymakers, and stakeholders in informing decision-making, improving sustainable practices, and setting future targets. © 2025	Environmental management;Performance indicators;Proximity to target;Sustainability;Textile firm	10.1016/j.sftr.2025.101496
21	Bury, M. and Feliks, J. and Kapłan, R.	2025	Assessing Efficiency in the Circular Economy	Energies	The growing importance of environmental technologies in a circular economy requires the use of tools that allow a realistic assessment of their economic efficiency. Classical investment indicators, such as NPV or IRR, are proving inadequate in the case of installations whose main objective is not to maximise profit but to reduce waste and emissions. There is a lack of tools in the literature that would allow for an unambiguous assessment of the unit cost of waste	cost analysis;cost-effectiveness of environmental technologies;investment subsidies;Levelized Cost of Waste (LCOW);tariff	10.3390/en18215615

			Using the Levelized Cost of Waste: A Case Study of Textile Waste Pyrolysis		treatment, taking into account the life cycle of the installation and market conditions. This study aims to assess the feasibility of using the Levelised Cost of Waste (LCOW) indicator, modelled on the Levelised Cost of Energy (LCOE) from the energy sector, as a planning and decision-making tool in the waste management sector. In this study, an LCOW calculation model was developed and applied to analyse textile waste pyrolysis technology. Simulations were conducted for three plant scales (1000, 5000, and 10,000 Mg/year), and a sensitivity analysis was performed to examine the relationship between the LCOW and by-product prices, energy costs, capital expenditures, and CO<inf>2</inf> emissions. The results confirm that the LCOW is a helpful tool for determining tariffs, identifying subsidy thresholds and comparing technology options. Its application is particularly well suited to small-scale environmental investments where classical approaches fail. © 2025 by the authors.	planning;textile pyrolysis;waste management;Cost accounting;Cost effectiveness;Decision making;Environmental management;Environmental technology;Investments;Life cycle;Pyrolysis;Sensitivity analysis;Waste treatment;Case-studies;Circular economy;Cost analysis;Cost-effectiveness of environmental technology;Investment subsidy;Levelized cost of waste;Levelized costs;Tariff planning;Textile pyrolyse;Waste pyrolysis;Cost benefit analysis	
22	Chaudhari, U.S. and Watkins, D.W. and Handler, R.M. and Reck, B.K. and Johnson, A.T. and Hossain, T. and Hartley, D.S. and Thompson, V.S. and Shonnard, D.R.	2025	Environmental and socio-economic Pareto-front trade-off analysis of U.S. PET packaging material in a circular economy	Sustainable Production and Consumption	Various recycling technologies are emerging to implement circular economy in plastics supply chain systems. However, the environmental and socio-economic trade-offs of plastics in circular economy are not well understood at a systems level. Particularly, quantifying these trade-offs as a function of end-of-life (EOL) management decisions, including transition of recycling technologies, systems level metrics such as circularity, recycled content, and the need for fossil-derived plastics are not well understood. The present study addressed these research gaps by applying a systems analysis modeling approach that utilizes material flow analysis, life cycle assessment, socio-economic data, and system optimization techniques for polyethylene terephthalate (PET) packaging supply chains in the United States. Pareto-front trade-offs between conflicting environmental and socio-economic impacts as well as those between socio-economic impacts and circularity were explored using the epsilon constraint method. The Pareto-front trade-off analysis revealed the transition of EOL management strategies for PET packaging systems, including changes in selection of recycling technologies, to aid decision making process by quantifying studied system metrics. Transitioning from environmentally optimal to socio-economically optimal systems led to increased employment (by 17 %), wages (by 26 %), and revenues (by 6 %) but also led to increased global warming potential (GWP; by 65 %), energy consumption (by 59 %), and reliance on fossil PET in the system (by 78 %). Finally, the results show that there is not a unique set of recycling technologies to achieve a sustainable circular economy of PET packaging system, instead it depends on the decision maker's objectives and targeted metrics of the system. © 2025 Institution of Chemical Engineers	Circular economy;Optimization;Pareto-front trade-offs;Socio-economics;Sustainability;Waste plastics;Circular economy;Decision making;Economic analysis;Economic and social effects;Environmental technology;Life cycle;Packaging;Packaging materials;Plastic bottles;Plastic recycling;Sustainable development;Systems analysis;Environmental economics;Optimisations;Pareto front;Pareto-front trade-offs;Recycling technology;Socio-economics;Terephthalate;Trade off;Waste plastic;Optimization	10.1016/j.spc.2025.09.009
23	Ahmad, A. and Javed, M.H. and Musharavati, F. and Khan, M.I. and Al-Muhtaseb, A.H. and	2025	Achieving circular economy through sustainable biofertilizer productio	Biomass Conversion and Biorefinery	The current study aims to examine the advanced environmental and technoeconomic performances of sustainable biofertilizer production from mixed municipal solid waste (MSW) using a life cycle assessment (LCA) approach. This research was conducted in a compost company involving raw material, transportation, and manufacturing stages in Lahore city as a case study by applying the combined LCA and life cycle costing (LCC) approach. GaBi, ReCiPe mid-point (H), the database was used to analyze the environmental burdens and economic modelling was assessed using techno-economic and statical methods. The key findings revealed that the key contributors to the environmental	Biofertilizer;Circular economy;Environmental technology;Life cycle assessment;Sustainability;Waste management;Cleaner production;Composting;Eutrophication;Life cycle assessment;Municipal solid waste;Photochemical	10.1007/s13399-025-06709-z

	Naqvi, M. and Abu, R. and Anjum, M.W. and Rehan, M. and Asam, Z.-U.-Z. and Hussain, R. and Nizami, A.-S.		n from mixed municipal waste: a life cycle analysis approach		degradation were global warming potential, marine water eutrophication potential, and terrestrial ecotoxicity potential, with contribution values of 1.21 + E03 kg CO<inf>2</inf> Eq, 7.05E + 02 kg N Eq, respectively. Grid mix energy use contributed more than 70% of impact scores to the total environmental performance. Scenario analysis was conducted to alter the energy source stage's key substance grid mix electricity with photovoltaic energy. It exhibited that photovoltaic energy can significantly reduce major environmental categories, including stratospheric ozone depletion and photochemical ozone formation, by 85% and 77%. The total LCC of FWC production from 1 metric ton of mixed MSW was calculated at 36.6$/t. Equipment cost was the top contributor (over 45%) of LCC for FWC production. MSW's estimated total revenue is 29.2 $/t, and 1586.1$/t daily. The payback is less than 3.5 years, which is more economically feasible. Hence, the FWC production is a win–win situation and is an economically feasible and profitable project. These outcomes could be helpful to policymakers and related enterprises in decision-making. © The Author(s), under exclusive licence to Springer-Verlag GmbH Germany, part of Springer Nature 2025.	forming;Sustainable development;Waste management;'current;Analysis approach;Biofertilizers;Circular economy;Environmental performance;Life cycle analysis;Life cycle costing;Municipal waste;Photovoltaic energy;Technoeconomic performance	
24	Piccoli, I. and Grillo, F. and Furlanetto, I. and Ragazzi, F. and Obber, S. and Bonato, T. and Meneghetti, F. and Ferlito, J. and Saccardo, L. and Morari, F.	2025	On-farm experimentation of anaerobic digestate distribution methods for advancing circular economy in the agroecosystem	Precision Agriculture	Purpose: This study evaluates the effectiveness of various anaerobic digestate distribution methods, including liquid digestate with a nitrification inhibitor, liquid digestate applied with variable rate application (VRA), and solid digestate, compared to mineral fertilizer. The objective was to assess their agronomic performance, nitrogen use efficiency (NUE), and environmental impact in winter wheat production within a circular economy framework. Method: A two-year on-farm experiment was conducted across two farms covering a total area of 47 hectares. The treatments evaluated included liquid digestate with nitrification inhibitor (LD+), liquid digestate with variable rate application (VRA), liquid digestate with both nitrification inhibitor and VRA, solid digestate (SD) and mineral fertilizer (MF) with or without VRA. The study measured wheat yields, protein content, nitrogen use efficiency (NUE), and compared the agro-environmental sustainability of digestate and mineral fertilizer applications. Results: Winter wheat production under digestate applications achieved yields (>5.9 t ha−1) and protein content (>5.3%) comparable to mineral fertilizer. The mineral fertilizer showed higher NUE (69%) than all digestate fractions, with LD+ at 43% and SD at 25%. The liquid digestate application with VRA increased NUE to 49%, but the nitrification inhibitor had no significant effect on NUE.The agronomic performance of solid digestate was comparable to mineral fertilizer at one site but lower at the other. However, solid digestate exhibited lower agro-environmental sustainability. Conclusion: Liquid fractions of anaerobic digestate can serve as alternatives to mineral fertilizers, providing promising agronomic results when combined with precision farming techniques such as VRA. However, their NUE and overall performance were lower than mineral fertilizers, with variability across sites due to soil conditions and environmental factors. Solid digestate demonstrated mixed agronomic outcomes and raised concerns regarding its longer-term impact on soil sustainability. Further long-term studies are needed to assess its full effects on soil structure and organic matter dynamics. © The Author(s) 2025.	Nitrification inhibitor;Nitrogen use efficiency;Nitrogen use efficiency;Variable rate application;Winter wheat;agricultural ecosystem;anaerobic digestion;circular economy;environmental impact;experimental study;inhibitor;nitrification;nitrogen;organic matter;soil structure;wheat	10.1007/s11119-025-10275-9
25	Gonçalves, A. and Leite, B.R. and Silva, C.	2025	Sustainability Index in Apparel: A Multicriteria Model Covering	Sustainability (Switzerland)	Consumers are increasingly willing to choose more sustainable products, driven by affordability and sustainability considerations. However, they often face difficulties in understanding the multitude of product certifications and identifying "greenwashing" marketing claims. This highlights the need for a clear and harmonized sustainability scoring system that allows consumers to benchmark products. Sustainability encompasses three key pillars: environmental, social, and economic. Accurately scoring a product's sustainability requires addressing a wide range of criteria within these pillars, introducing significant complexity. This study proposes a multicriteria methodology for scoring the sustainability of apparel	circular economy;digital product passport;fashion;key performance indicators;life cycle assessment;product sustainability index;recyclability;textile;traceability;circular economy;cotton;durability;environmental impact;life cycle	10.3390/su17178004

			Environmental Footprint, Social Impacts, and Durability		products into an A to E label. The approach combines a life cycle assessment covering environmental impacts from "farm-to-gate", with a social evaluation based on country-level social key performance indicators (KPIs) and factory-specific data aligned with the International Labour Organization (ILO). Additionally, the sustainability score incorporates the impact of product durability, as longer-lasting products can reduce environmental footprint and costs for consumers. The methodology is defined and validated through a case study of a white T-shirt produced with 50% recycled cotton and 50% organic cotton. The results demonstrate the comprehensive assessment of the T-shirt's environmental and social impacts, providing a detailed sustainability score, highlighting the role of recyclability. This comprehensive sustainability scoring system aims to provide consumers with a clear, harmonized, and reliable assessment of product sustainability, empowering everyone to make informed purchasing decisions aligned with their values. It will also enable brands and retailers to calculate the sustainability score of their products, including in the scope of digital product passport, provided they can ensure traceability and transparency along the supply chain. © 2025 by the authors.	analysis;model validation;social impact;supply chain management;textile industry	
26	Nadeem, A. and Tariq, M.A.U.R. and Safi, A.R. and Malik, Z.M. and Sarwar, K. and Rajabi, Z.	2025	Life cycle assessment of a textile industry for environmental impacts under alternative operational scenarios	Water Science and Technology	Pakistan's fresh water supply declined significantly from 5,260 to 1,014 m3/person/year between 1950 and 2018. Water-intensive operations of the textile industry further aggravate this fresh water scarcity by contributing significant pollution. This study uses life cycle assessment (LCA) to examine the environmental effects of textile production with emphasis on human health, resources, and ecosystem. Potential sustainable solutions are offered by innovations like energy efficiency techniques and closed-loop water recycling systems. Environmental trade-offs in this study are measured between energy optimization and water recycling. Effects such as resource depletion (RD), global warming potential (GWP), and eutrophication potential (EP) are evaluated. The efficacy of these integrated techniques is demonstrated in results. Energy optimization and integrated solutions reduce GWP by 30.7 and 33.1%, respectively, and water consumption by 43.6 and 43.9%, respectively. However, these approaches also result in trade-offs, including increased freshwater ecotoxicity and depletion of fossil resources. In summary, combining renewable energy with water recycling has significant environmental advantages, but long-term sustainability necessitates rigorous trade-off management and optimization. The textile sector should adopt similar circular economy strategies, supported by robust data collection and monitoring frameworks. © 2025 The Authors.	environmental impacts;LCA;sustainability;textile industry;trade-offs;Artificial life;Circular economy;Economic and social effects;Energy efficiency;Life cycle;Life cycle assessment;Textiles;Water pollution;Water recycling;Energy optimization;Fresh Water;Global warming potential;Health Resources;Human health;Operational scenario;Pakistan;Textile production;Trade off;Water scarcity;Sustainable development;Textile industry;alternative energy;circular economy;energy efficiency;environmental impact assessment;eutrophication;global warming;life cycle analysis;recycling;resource depletion;sustainability;textile industry;trade-off;water supply;Article;economic aspect;ecotoxicity;environmental impact;fluid intake;fossil;global warming potential;life cycle assessment;nonhuman;pharmaceutics;renewable energy;water	10.2166/wst.2025.123

						insecurity;ecosystem;environment;environmental protection;greenhouse effect;Conservation of Natural Resources;Ecosystem;Environment;Eutrophication;Global Warming;Recycling;Textile Industry;Water Supply	
27	Chen, P. and Steuer, B. and Wu, G. and Dong, L. and Tong, X. and de Jong, M. and Sauerwein, M.	2025	A life cycle assessment on food delivery packaging in Guangzhou, China: Using consumer preferences to infer viable circular economy policy pathways	Journal of Environmental Management	The fast growth of food delivery services in China has vastly increased consumption and environmental impact of plastic-based, single-use food and beverage containers (FaBCs). A viable solution to curb plastic pollution from FaBCs is to apply circular economy (CE) principles in regulations, business models, and consumption patterns. The present paper centers on FaBCs from food deliveries in Guangzhou and uses first-hand data on FaBC waste generation to evaluate the resulting environmental impacts via a life cycle assessment (LCA). Having tested five LCA scenarios centering on CE principles, a 'combined scenario' comprising refuse, reduce, reuse, and recycling strategies was found effective in reducing emissions and water use by 25.5 %–66.4 %. Taking these quantitative findings as benchmarks for what circular policy should deliver, the paper synthesizes various CE measures proven effective within and outside of China into implementable policy scenarios. By merging producer responsibility schemes, reverse logistics, Internet-of-Things applications as well as an alternation of bans with the use of reusables, the paper outlines three pathways towards an evidence-based, viable circular policy transition for food deliveries in Guangzhou. © 2025 Elsevier Ltd	Circular economy;Food and beverage containers (FaBCs);Food delivery sector;Life cycle assessment (LCA);Benchmarking;Food waste;Life cycle;Life cycle assessment;Beverage containers;Circular economy;Consumers' preferences;Fast growths;Food and beverage container;Food containers;Food delivery;Food delivery sector;Guangzhou;Beverages;polyethylene;polylactic acid;polypropylene;water;plastic;beverage;business;circular economy;consumption behavior;environmental impact;life cycle analysis;packaging waste;water use;Article;catering service;China;city;community;consumer attitude;controlled study;economic aspect;environmental mitigation;environmental policy;flow measurement;food packaging;greenhouse gas emission;internet of things;life cycle assessment;quantitative analysis;recycling;waste;wood;Guangdong;Consumer Behavior;Food Packaging;Plastics;Recycling	10.1016/j.jenvman.2025.126478
28	Falsafi, A. and Togiani, A. and Colley, A. and Varis, J. and	2025	Life cycle assessment in circular design	Journal of Cleaner Production	This study systematically examines the role of Life Cycle Assessment (LCA) in supporting and validating Circular Design (CD) strategies across industries. Using the PRISMA framework, 99 studies were analyzed to assess how LCA has been applied to evaluate the effectiveness of circular strategies. The findings reveal that Resource Efficiency and Waste Minimization (32.5 %) and End-of-Life Planning (27.8 %) are the most frequently assessed strategies. In contrast, Product	Circular design (CD);Circular design strategies (CDS);Circular economy (CE);Environmental impact assessment;Life cycle	10.1016/j.jclepro.2025.146188

	Horttanainen, M.		process: A systematic literature review		Longevity (10.8 %), Circular Business Models (14.2 %), and Sustainable Materials (14.6 %) receive comparatively less attention. The construction sector (38 %) demonstrates the highest implementation of multiple circular strategies, followed by the automotive industry (32 %), where LCA has been instrumental in validating material efficiency and lightweighting approaches. While packaging and wind energy sectors show targeted applications of LCA in closed-loop systems and material recovery, industries such as textiles (8 %), chemicals (12 %), and marine applications (6 %) remain underrepresented. LCA plays a critical role in quantifying the environmental benefits and trade-offs of circular strategies, offering valuable insights into resource optimization, emissions reduction, and waste minimization. By assessing hotspots and performance metrics, LCA helps designers, manufacturers, and policymakers make informed decisions on circular interventions. However, methodological inconsistencies, data limitations, and the lack of standardized metrics for evaluating multi-strategy synergies hinder broader implementation. Additionally, certain strategies, such as Water Efficiency and Additive Manufacturing (2 % each), remain largely unexplored despite their relevance to circular economy objectives. To address these gaps, future research should prioritize standardizing LCA methodologies, expanding its application in underrepresented sectors, and developing a more structured approach to evaluating synergies between circular strategies. By offering a unified CDS classification and cross-sectoral synthesis, this review supports the effective integration of LCA in circular design practices and provides actionable insights for future research, industry application, and policy development. © 2025 The Authors	assessment (LCA);Sustainability;Artificial life;Automotive industry;Circular economy;Closed loop systems;Construction industry;Ecodesign;Economic and social effects;Environmental impact;Industrial economics;Life cycle;Life cycle assessment;Reviews;Circular design;Circular design strategy;Circular designs;Circular strategies;Design strategies;Impact assessments;Sustainable development	
29	Petrucci, R. and Menegaldo, G. and Rocchi, L. and Paolotti, L. and Boggia, A. and Puglia, D.	2025	Olive Oil Wastewater Revalorization into a High-Added Value Product: A Biofertilizer Assessment Combining LCA and MCI	Sustainability (Switzerland)	The olive oil sector constitutes a fundamental pillar in the Mediterranean region from socio-economic and cultural perspectives. Nonetheless, it produces significant amounts of waste, leading to numerous environmental issues. These waste streams contain valuable compounds that can be recovered and utilized as inputs for various applications. This study introduces a novel value chain for olive wastes, focused on extracting lignin from olive pomace by ionic liquids and polyphenols from olive mill wastewater, which are then incorporated as hybrid nanoparticles in the formulation of an innovative starch-based biofertilizer. This biofertilizer, obtained by using residual wastewater as a source of soluble nitrogen, acting at the same time as a plasticizer for the biopolymer, was demonstrated to surpass traditional NPK biofertilizers' efficiency, allowing for root growth and foliage in drought conditions. In order to recognize the environmental impact due to its production and align it with the technical output, the circularity and environmental performance of the proposed system were innovatively evaluated through a combination of Life Cycle Assessment (LCA) and the Material Circularity Indicator (MCI). LCA results indicated that the initial upcycling process was potentially characterized by significant hot spots, primarily related to energy consumption (>0.70 kWh/kg of water) during the early processing stages. As a result, the LCA score of this preliminary version of the biofertilizer may be higher than that of conventional commercial products, due to reliance on thermal processes for water removal and the substantial contribution (56%) of lignin/polyphenol precursors to the total LCA score. Replacing energy-intensive thermal treatments with more efficient alternatives represents a critical area for improvement. The MCI value of 0.84 indicates limited potential for further enhancement. © 2025 by the authors.	biofertilizer;LCA;lignin;MCI;olive mill wastewater;olive pomace;polyphenols;biofertilizer;drought;environmental impact;secondary metabolite;wastewater treatment	10.3390/su17156779
30	Cortes, Antonio and Oliveira, Luis F. S. and Ferrari, Valdecir and Taffarel,	2020	Environmental assessment of viticulture waste valorisati	ENVIRONMENTAL POLLUTION	Composting is a solid waste management alternative that avoids the emission of methane associated with its disposal in landfill and reduces or eliminates the need for chemical fertilisers if compost is applied. The main objective of this study was to analyse the environmental burdens of composting as a way to achieve a more circular valorisation of wine waste. To do so, with the purpose of identifying optimal operational conditions and determining the "hotspots" of the process, the life cycle assessment (LCA) methodology was used. The consumption of diesel		10.1016/j.envpol.2020.114794

	Silvio R. and Feijoo, Gumersindo and Teresa Moreira, Maria		on through composting as a biofertilisation strategy for cereal and fruit crops		fuel in machinery was determined to be the main critical point in the environmental effects of the system, followed by the transport and distribution of the compost. After the application of compost instead of mineral fertilisers, corn, tomato and strawberry crops would have a better environmental performance in most impact categories. In this sense, a maximum improvement of 65% in terrestrial ecotoxicity is achieved in strawberry cultivation. In light of the results obtained, it is demonstrated that composting is a suitable way of organic waste valorisation according to Circular Economy principles. (C) 2020 Elsevier Ltd. All rights reserved. PU - ELSEVIER SCI LTD PI - OXFORD PA - THE BOULEVARD, LANGFORD LANE, KIDLINGTON, OXFORD OX5 1GB, OXON, ENGLAND	
31	Arfelli, Francesco and Pizzone, Daniela Maria and Cespi, Daniele and Ciacci, Luca and Ciriminna, Rosaria and Calabro, Paolo Salvatore and Pagliaro, Mario and Mauriello, Francesco and Passarini, Fabrizio	2023	Prospective life cycle assessment for the full valorization of anchovy fillet leftovers: The LimoFish process	WASTE MANAGEMENT	Prospective life cycle assessment models were developed and applied at the laboratory and industrial scale with the aim to evaluate the environmental burdens associated with the LimoFish process used to produce the fish oil "AnchoiOil", the new organic fertilizer "AnchoisFert" or biogas (by means of anaerobic digestion) after treatment of anchovy fillet leftovers (AnLeft) with agro-solvent d-limonene. Potential impacts for climate change and freshwater eutrophication were estimated at 29.1 kg CO2 eq/kg AnLeft and 1.7E-07 kg PO4 eq/kg AnLeft at laboratory scale, and at 1.5 kg CO2 eq/kg AnLeft and 2.2E-07 kg PO4 eq/kg AnLeft at industrial scale. Electricity consumption is the main contributor to the environmental impact of the process and plays a significant role in the production of d-limonene, for which cold pressing extraction would reduce the related impacts by similar to 70 %. The use of the solid by-product as organic fertilizer or input to anaerobic digestion would provide additional environmental benefits to the process. The LimoFish process is a successful example of a low impacting strategy to reduce the demand for natural resources and maximize the application of the circular economy principles in the fishing industry. PU - PERGAMON-ELSEVIER SCIENCE LTD PI - OXFORD PA - THE BOULEVARD, LANGFORD LANE, KIDLINGTON, OXFORD OX5 1GB, ENGLAND	10.1016/j.wasman.2023.06.002
32	Lehtoranta, Suvi and Laukka, Vuokko and Vidal, Brenda and Heiderschei dt, Elisangela and Postila, Heini and Nilivaara, Ritva and Herrmann, Inga	2022	Circular Economy in Wastewater Management-The Potential of Source-Separating Sanitation in Rural and Peri-Urban Areas of Northern Finland and Sweden	FRONTIERS IN ENVIRONMENTAL SCIENCE	Current practices in wastewater management lead to inefficient recovery and reuse of nutrients and can result in environmental problems. Source separation systems have been shown to be an efficient way of recovering nutrients and energy from wastewaters, both in rural and urban context. Studies on nutrient recovery potential and life cycle impacts of source separation systems are mainly limited to small systems (for example a few households) while the impacts of upscaling source separation to a regional level have hardly been studied, especially in sparsely populated areas where the cost of the connection to a main treatment plant is higher. This study examines the regional nutrient balance of two source separation scenarios-black water separation and urine diversion-and compares them to the existing conventional wastewater system. The analysis comprises three sparsely populated regions of northern Finland and Sweden, including rural, peri-urban and urban areas. In addition, climate impacts are assessed based on existing life cycle assessment (LCA) studies. According to the results, by source separation it is possible to achieve a significant increase in the recovery rate of phosphorus (41-81%) and nitrogen (689-864%) compared to the conventional system. Depending on the region up to 65% of the mineral phosphorus and 60% of mineral nitrogen fertilisers could be theoretically replaced. Furthermore, the climate and eutrophication impacts would decrease with the implementation of such systems, but an increase in acidification may occur. However, even if the benefits of source separation systems are undisputed in terms of nutrient recovery, the implementation of such systems would to a large extent require an entire system	10.3389/fenvs.2022.804718

					change of the wastewater treatment sector and a wide paradigm change towards a circular economy. PU - FRONTIERS MEDIA SA PI - LAUSANNE PA - AVENUE DU TRIBUNAL FEDERAL 34, LAUSANNE, CH-1015, SWITZERLAND		
33	Iglesias, H. and Paredes Ortiz, A. and Pereira Sánchez, Á. and Fernández-Gutiérrez, D. and Lara-Guillén, A.J.	2025	Measuring the Circularity of Bio-Based Fertilizers: Applying the BIORADAR Product Circularity Monitoring Framework	Applied Sciences (Switzerland)	Featured Application: A product circularity monitoring framework designed for bio-based fertilizers is applied to five products, being proposed as a managerial tool within product management and eco-design processes of eco-innovative firms. The transition to the circular economy (CE) is one of the EU's current strategic policies to improve its competitiveness and sustainability. While the EU has developed a framework for monitoring overall progress toward the CE, there are gaps in monitoring specific priority sectors, such as the bioeconomy. In order to support industry and policymakers in this sector, this paper presents the application of the BIORADAR's product circularity monitoring framework to five bio-based fertilizers. The framework is composed of two publicly available indicators: the circular index and the circularity indicator of nutrient; and two new indicator proposals: the biodegradable content and the nutrient slow-release index. Making use of life cycle inventories and supplementary data from the scientific literature, these four indicators were calculated for algae biomass, compost, feather meal, spent mushroom substrate, and wood vinegar. The framework proved to be useful for measuring the circularity at the product level for bio-based fertilizers, especially shedding light on the virgin non-renewable materials consumption, waste generation, biodegradability, nutrient recovery process efficiency, and nutrient release speed. It constitutes the first approach to measuring circularity tailored to bio-based fertilizer. By incorporating it into eco-design, innovation, and managerial decision-making processes, key stakeholders can rely on guiding metrics to support their transition toward higher circularity levels. © 2025 by the authors.	biofertilizers;circular economy indicators;circularity assessment;eco-design tools;Circular economy;Competition;Ecodesign;Economic and social effects;Fertilizers;Life cycle;Nutrients;Product design;Sustainable development;Bio-based;Biofertilizers;Circular economy indicator;Circularity assessment;Design-process;Eco-design tools;Innovative firms;Monitoring frameworks;Product management;Biodegradability	10.3390/app15147701
34	Fidan, F.Ş. and Kızılkaya Aydoğan, E.K. and Uzal, N.	2025	Comprehensive analysis of social subcategories throughout life cycle assessment approach for the textile industry	International Journal of Life Cycle Assessment	Purpose: While the environmental and economic aspects of sustainability have been extensively studied, social sustainability has been largely neglected and necessitates a thorough investigation. The study examines the intricate nature of social impact assessments, considering the substantial significance of the textile industry in the global economy and its wide-ranging social implications. This study comprehensively examines critical social subcategories used in the life cycle assessment (LCA) methodology to highlight the social sustainability of the textile sector. The objective of the study is to enhance and optimize the subcategories proposed by UNEP/SETAC for social LCA by examining, expanding, and adapting them specifically to the textile industry, offering a more focused and sector-specific viewpoint on key metrics. Methods: The study examines its use in textile production and distribution by first carefully evaluating the subcategories established by UNEP/SETAC for social LCA. A systematic assessment of positive and negative social impacts throughout the entire supply chain is examined through global standards, textile-specific standards, and literature. Analysis of semi-structured stakeholder interviews and a comprehensive literature review reveals important social subcategories, some of which go beyond the S-LCA guidelines. Results: New social metrics, including quality, women's rights, gender pay gap, collaboration with NGOs, academic research, circularity implementation, and environmental issues, were formulated from stakeholders' perspectives, tailored specifically for the textile sector. Conclusions: The results of the study aim to promote a socially sustainable textile industry by guiding stakeholders to make informed decisions and adopt methods that prioritize social responsibility as well as environmental and economic factors. © The Author(s) 2024.	S-LCA guidelines;Social life cycle assessment;Social protection;Stakeholder;Textile industry;UNEP/SETAC;Economic and social effects;Supply chains;Sustainable development;Textile industry;Textiles;Assessment approaches;Comprehensive analysis;S-life cycle assessment guideline;Social life;Social life cycle assessment;Social protection;Social sustainability;Stakeholder;Textile sector;UNEP/SETAC;Life cycle;Article;community;economic aspect;environmental sustainability;gender;government;human;life cycle assessment;non-governmental organization;practice guideline;social life;social responsibility;textile	10.1007/s11367-024-02340-8

						industry;women's rights;worker	
35	Haslinger, A.-S. and Huysveld, S. and Cadena, E. and Dewulf, J.	2025	Guidelines on the selection and inventory of social life cycle assessment indicators: a case study on flexible plastic packaging in the European circular economy	International Journal of Life Cycle Assessment	Purpose: Emerging technologies are addressing current challenges to shift from a linear to a circular economy. However, the consideration of social aspects in this context is limited, and the prioritization of indicators appears arbitrary in the absence of clear and robust selection criteria. Following social life cycle assessment (S-LCA) principles, the aim of this paper is to guide the selection and inventory of social indicators based on a case study on evolving flexible packaging within the European circular economy. Methods: To achieve the objective, the study involves several steps, including conducting a systematic literature review to identify key stakeholders, impact subcategories, indicators, and inventories for circular flexible plastic packaging. Multi-criteria decision analysis (MCDA) is applied to preselect a set of indicators, followed by stakeholder engagement in prioritizing impact indicators through participatory methods. Subsequently, a data collection procedure was established. Results and discussion: This paper presents a materiality ranking for 19 social indicators tailored to the emerging circular flexible packaging. The result is a prioritization of nine of these indicators, including Existence of record of proof of age, Percentage of workers who are paid a living wage or above, and Existence of certified environmental management system. These nine indicators form the basis for the collection of respective inventory data for an entry-level assessment. Furthermore, guidelines on 11 procedural steps were formulated based on these findings. Moreover, challenges of synonymity and inconsistency in S-LCA terminology, besides inaccessible inventory data especially in the context of evolving recycling technologies, are identified as substantial barriers in the effort to streamline and perform S-LCA. Conclusions: The paper concludes that prioritizing indicators is essential for entry-level and prospective assessments, especially when time and data are limited. Additionally, using primary inventory data to evaluate the foreground system and its direct impacts on stakeholders promotes accountability and corporate social responsibility. Furthermore, a set of procedural steps, from defining the system boundary to preparing the data questionnaire, serves as a valuable resource for practitioners across diverse industries. Recommendations: In future research, these nine prioritized indicators can be applied to assess the social performance of various case studies along the value chain of circular flexible plastic packaging, covering food and non-food applications. In addition, the methodological guidelines for selecting and prioritizing indicators can be replicated across multiple industry sectors. Moreover, research effort should be directed towards establishing a methodological framework for prospective S-LCA in the context of emerging technologies. © The Author(s) 2024.	Circular economy;Flexible plastic packaging;Materiality assessment;Social indicators;Social inventory data;Social life cycle assessment;Stakeholder participation;Data acquisition;Decision making;Economic and social effects;Environmental management;Human resource management;Packaging;Packaging materials;Social aspects;Circular economy;Flexible plastic packaging;Flexible plastics;Inventory data;Materiality assessment;Plastic packaging;Social indicators;Social inventory data;Social life;Social life cycle assessment;Stakeholder participation;Life cycle;Article;decision making;economic aspect;environmental management;feasibility study;flexible plastic packaging;human;life cycle assessment;packaging;practice guideline;quantitative analysis;questionnaire;social life;stakeholder engagement;systematic review	10.1007/s11367-024-02312-y
36	Köck, B. and Spatt, P. and Archodoulaki, V.-M. and Mihalyi-Schneider, B.	2025	Life cycle inventory data generation for yogurt packaging in Austria	Cleaner Environmental Systems	This study addresses a critical gap in life cycle assessment (LCA) data for yogurt packaging within the Austrian market, emphasizing the need for accurate, localized information on packaging materials, transport distances, and end-of-life processes. Through detailed measurements of yogurt cup weights, material compositions, and packaging configurations, this research provides foundational data that enhance the precision of LCAs specific to Austria. Key findings reveal that yogurt cups in Austria are primarily made from polypropylene (PP) and polystyrene (PS), with notable variations in weight and sleeve types across different filling sizes, including paper-sleeved and non-sleeved options. This offers valuable insights for optimizing packaging design in line with circular economy and Green Deal goals. By supplying robust, Austria-specific Life Cycle Inventory (LCI) data, this study supports targeted strategies for material efficiency and sustainability in yogurt packaging, ultimately aligning with broader EU objectives for waste reduction and resource conservation. © 2025 The Authors	Data generation;Food packaging;Life cycle assessment;Life cycle inventory analysis;Plastic;Yoghurt;Austria;Data generation;Food packaging;Inventory data;Life Cycle Inventory;Life cycle inventory analysis;Localised;Material transport;Transport distances;Yogurt;Packaging materials	10.1016/j.cesys.2025.100271

37	Barahmand, Z. and Eikeland, M.	2025	EcoStrategic index: Economic value creation through product portfolio diversity for waste-to-x technologies	Renewable and Sustainable Energy Reviews	Sustainable decision-making for waste-to-X technologies presents a challenge, encompassing numerous alternatives across the entire supply chain, from biomass selection to diverse product portfolios. Each decision affects sustainability assessments, which span environmental, economic, social, technological, and circularity aspects. Addressing a gap in aligning product portfolio management with circular economy principles, this study introduces the EcoStrategic Index, a composite metric to quantify economic values within potential product portfolios. As part of a broader framework, the EcoStrategic Index integrates seamlessly with other dimensions to support strategic decision-making. Employing the value pyramid of bio-products concept, this study establishes a benchmark classification of chemicals with expert-informed values. Empirical validation was performed through a comparative case study of gasification and pyrolysis technologies, with catalogued product portfolios of approximately 300 and 1000 entries, respectively. Results show that over 50 % of both portfolios consist of functionalized hydrocarbons, with pyrolysis yielding a greater share of fine chemicals (28 %) compared to gasification (1 %), while gasification produces a larger share of inorganic salts and fertilizers (7 %). EcoStrategic Indices indicate that pyrolysis scores equal to or higher than gasification across all five sub-indices in multiple scenarios. To demonstrate its integrability, the TechnoStraegic Index was introduced, adding technology readiness level concept to form a cross-dimensional index reflecting economic value creation and technological maturity. The results show that while pyrolysis exhibits stronger potential for economic value, gasification often outperforms in cross-dimensional evaluations due to considerable higher technological maturity. This framework offers a cost-effective tool for guiding technology selection and strategic planning toward sustainable goals. © 2025 The Authors	Circular economy index;Composite index;Economic value;EcoStrategic index;Product portfolio diversity;Technology readiness level;Cost effectiveness;Circular economy;Circular economy index;Composite index;Economic value creation;Economic values;Economy index;Ecostrategic index;Product portfolio diversity;Product portfolios;Technology readiness levels	10.1016/j.rser.2025.115507
38	Biyada, S. and Jawhari, F.Z. and Urbonavičius, J. and Merzouki, M.	2025	Assessment of Textile Waste Circularity through Composting Using the Seed Germination Index as Indicator for a Sustainable Management	Waste and Biomass Valorization	Nowadays, the world is dealing with a textile waste management problem that affects both human health and the environment. As one of the cornerstones of the circular economy, composting is described as an effective green technology for recycling of such type of waste. The further usage of such compost is not possible without examination of the genotoxic and phytotoxic effects of the final product. Here, we examined the effect of initial feedstock concentration on the biosafety of textile compost. Three mixtures were analyzed using textile waste mixed with green waste and paper and cardboard waste as the input feedstock. Such mixtures were processed by the silo composting method and the phyto-toxicity of the obtained compost was assessed using the germination index. Moreover, to explain the results obtained, analysis of physical-chemical parameters (pH, electrical conductivity, carbon/nitrogen (C/N) ratios, ammonium and nitrate ratios, and humic substances ratio (E<inf>6</inf>/E<inf>4</inf>)) as well as total heavy metal (Cr, Cu, Ni and Zn) and Na+, P, K+, Mg2+ and Fe contents were determined in initial mixtures and final compost products. Mixtures with 40% and 60% of textile waste at the final stage of composting were non-phytotoxic, with a germination index above 100%, a C/N ratio between 15 and 20, NH<inf>4</inf>+/NO<inf>3</inf>− ratios below 1 and E<inf>6</inf>/E<inf>4</inf> close to 5. All composts, even with a high concentration of textile waste (80%), fulfilled the requirements of the Canadian national standard for heavy metal content. This study proves that well-managed composting, whatever the nature of the feedstock and/or the concentration used, produces a high-quality organic amendment which increases the yield and quality of plant biomass. © The Author(s), under exclusive licence to Springer Nature B.V. 2024.	Biomass;Biotechnology;Circular economy;Compost;Phytotoxicity;Textiles waste management;Composting;Feedstocks;Seed;Waste management;Carbon-nitrogen ratio;Circular economy;Germination index;Green technology;Human health;Management problems;Phytotoxicity;Seed germination;Sustainable management;Textile waste management;Concentration;Germination;Mixtures;Ratios;Textiles;Waste Management	10.1007/s12649-024-02819-3
39	Bolujoko, N. and Duling, A. and	2025	The fate of antibiotics during	Science of the Total Environment	The principles of circular economy encourage the recovery of phosphorus from nutrient-rich waste streams such as animal manure, domestic wastewater, and urine to supplement existing sources of raw phosphorus. However, these waste streams also contain a wide variety of contaminants of emerging concern including	Fertilizers;Manures;River pollution;Animal manure;Circular economy;Co-	10.1016/j.scitotenv.2025.178829

	Shashvatt, U. and Mangalgiri, K.		phosphate recovery processes - A critical review		antibiotics, and the recovery of phosphorus from these waste streams results in the co-occurrence of antibiotics with the recovered phosphorus products. This paper provides a comprehensive overview of the fate of environmentally relevant antibiotics in three major existing and upcoming phosphorus recovery processes: precipitation-, membrane-, and adsorption-based treatment. In general, the co-occurrence of antibiotics in recovered phosphorus increases with the presence of dissolved organic matter (DOM) and cations due to π-π interaction and cationic bridge formation, respectively. Additionally, antibiotics display pH-based speciation resulting in electrostatic interactions with recovered phosphorus at pH > 7.0. Furthermore, this critical review establishes a new metric, the relative antibiotic-to-phosphorus (RAP), defined as the ratio of the concentration of antibiotics to phosphorus in recovered phosphorus to that of the phosphorus-rich waste. Precipitation-based methods, particularly struvite, demonstrated the lowest RAP, while the RAP in carbon-based adsorbents was 1.8 × 108 times higher than in membrane-based processes. In reviewing literature on the fate of antibiotics in phosphorus recovery processes, several research needs are also highlighted: the fate of non-tetracycline antibiotics, simultaneous investigation of phosphorus and antibiotic fate in membrane- and adsorption-based methods, treatment methods to mitigate the co-occurrence of antibiotics in recovered phosphorus product, and the release of antibiotics from recovered phosphate products. © 2024	occurrence;Contaminants of emerging concerns;Critical review;Domestic wastewater;Phosphate recovery;Phosphorus recovery;Recovery process;Waste stream;Rivers;adsorbent;antibiotic agent;carbon;cation;phosphate;phosphorus;struvite;tetracycline;antiinfective agent;adsorption;antibiotics;critical analysis;dissolved organic matter;environmental fate;wastewater treatment;controlled study;manure;nonhuman;pH;precipitation;review;static electricity;wastewater;chemistry;procedures;sewage;water pollutant;Adsorption;Anti-Bacterial Agents;Phosphates;Phosphorus;Waste Disposal, Fluid;Wastewater;Water Pollutants, Chemical	
40	Sandin, G. and Lidfeldt, M. and Nellström, M.	2025	Exploring the Environmental Impact of Textile Recycling in Europe: A Consequential Life Cycle Assessment	Sustainability (Switzerland)	This study examines the environmental consequences of implementing textile-to-textile recycling at scale in the EU by 2035, as this is viewed as a key solution in the sustainable development of the European textile sector. Three research questions are addressed: (i) How likely is it that increased textile-to-textile recycling reduces climate and water deprivation impacts, (ii) What is the extent of these reductions (if any), and (iii) What are the most influential parameters affecting the results? The method used is a consequential life cycle assessment (LCA), coupled with a Monte Carlo analysis to systematically address uncertainties. Results show a 92% probability that increasing textile-to-textile recycling to 10% in the EU will reduce climate impact and an almost 100% probability that it will lower water deprivation impact. Sensitivity analyses indicate climate-impact reduction probabilities ranging from 62% to 98%, and water deprivation impact reduction probabilities consistently above 99%. While recycling is likely to reduce climate impact, there is a notable risk of an increase. On average, climate impact would be reduced by about 0.5%, and water deprivation impact by slightly more than 3%, relative to the estimated impact of current textile consumption in the EU. These reductions increase if the textile recycling sector focuses on producing fibers with low climate and water impact or high replacement rates are ensured. Still, additional measures beyond recycling are needed to cut the textile industry's environmental impact substantially. © 2025 by the authors.	apparel;circular economy;clothing;collaborative consumption;LCA;waste management;circular economy;climate effect;clothing industry;environmental impact assessment;exploration;life cycle analysis;Monte Carlo analysis;recycling;sustainable development;textile industry;Europe	10.3390/su17051931
41	Miao, C. and Zeller, V.	2025	Nutrient circularity from waste to fertilizer: A perspecti	Science of the Total Environment	Nutrient circularity, an exemplification of circular economy (CE), is situated in the waste/wastewater-agriculture nexus. Recycling nutrient elements from waste streams to fertilizer products amplify the sustainable management of resources and intersect technical and biological loops, a concept developed for CE. Such a complex system needs to be directed by robust assessment methods such as life cycle assessment (LCA) to identify trade-offs and potentials. This review aims to provide a comprehensive outlook of the current state of nutrient circularity and a	Global South;Impact assessment;Life cycle assessment;Life cycle inventory;Nutrient circular economy;System modeling;Fertilizers;Circular economy;Global	10.1016/j.scitotenv.2025.178623

			ve from LCA studies		critical analysis on the applicability of LCA to nutrient CE pathways. Our worked has summarized CE pathways including direct land application, traditionally integrated processes in wastewater treatment plants, and targeted nutrient recycling technologies. Despite the restrictions on inputs streams, recycling technologies demonstrated a relative low selectivity. LCA is a powerful instrument to guide nutrient circularity; however, system modeling settings can confine the applicability of LCA for CE pathways. Given that LCA studies can only partially capture the CE characteristics, a deliberate methodological selection of functional unit, allocation method and impact indicators is required for the specific CE aspect under investigation. Lower data scale limits the LCA ability to assess CE practices that requires systemic analyses. Hence, full scale assessment is of necessity since it incorporates potential gains and drawbacks from the material upscaling, process efficiency changes and possible industrial symbiosis. The findings of this review lay a robust groundwork for future research, pinpointing areas of focus in LCA modeling within nutrient circularity. This is particularly vital for the Global South to ensure knowledge transfer and prompt action. © 2025 The Author(s)	south;Impact assessments;Life Cycle Inventory;Nutrient circular economy;Nutrient elements;Recycling technology;Sustainable management;System models;Waste stream;fertilizer;environmental impact assessment;green economy;life cycle analysis;nutrient;recycling;sustainability;waste management;wastewater treatment;agriculture;economic aspect;human;life cycle;life cycle assessment;review;symbiosis;tight junction;waste;waste water treatment plant;wastewater	
42	Espinoza-Perez, Lorena A. and Espinoza-Perez, Andrea T. and Vasquez, Oscar C.	2024	Life cycle assessment of alternatives for industrial textile recycling	SCIENCE OF THE TOTAL ENVIRONMENT	The $882 billion textile trade in 2021 poses environmental concerns, highlighting the importance of encouraging a circular economy to attain sustainable textiles. Therefore, policies must prioritize textile recycling, particularly in developing countries, and sharing information throughout the value chain. This research aims to explore the potential environmental benefits of two industrial recycling processes for textile residues versus the traditional waste management and production process through a life cycle assessment applying the ReCiPe method at midpoint and endpoint levels focusing on generating significant data availability and broader assessment than existing literature to support decision making related to recycling systems for textile residues. Results related to the textile residues recycling process to obtain stripes (R1) and replace sawdust, to fill pushing balls, show that it would produce environmental benefits regardless of location in several midpoint categories. Furthermore, regarding the endpoint results, the DALY savings are mainly due to avoiding landfill, while the savings in ecosystem impacts are generated by avoiding landfill and sawdust production. Regarding the recycling process to obtain recycled yarn and fill (R2) net savings in global warming potential are generated if landfill avoidance is considered. Nevertheless, endpoint results show that DALYs of all the avoided processes correspond to 1.5 times the impacts of all the R2 recycling processes, mainly due to avoiding virgin yarn production. Therefore, both recycling processes are recommended. However, some strategies are required to generate greater benefits, such as applying the R2 recycling process as the first option for stretchable textile waste, and after being used, going through the R1 recycling process. In addition, the strategic placement of the R1 recycling facility should be distant from areas of sawdust production. A sensitivity analysis was carried out due to the variability of virgin products to replace in the market. PU - ELSEVIER PI - AMSTERDAM PA - RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS		10.1016/j.scitotenv.2024.172161
43	Penaranda, Diego and Casagli, Francesca and Morales, Marjorie	2025	Ex-ante LCA for circular resource management of liquid	JOURNAL OF INDUSTRIAL ECOLOGY	The simplest method for treating liquid digestate, which involves directly spreading it over local agricultural land, is facing scrutiny due to the challenges of transporting large volumes and the environmental risks posed by nitrogen and phosphorus pollutants. Improvements in liquid digestate treatment are necessary to mitigate these threats and support a growing circular economy. This study evaluates an advanced digestate treatment method that decouples hydraulic retention time (HRT) and solid retention time (SRT) in high-rate algal/bacterial		10.1111/jiec.70050

	and Beline, Fabrice and Bernard, Olivier		digestate, by predictive modeling of algae-bacterial processes		ponds (HRABPs). By combining life cycle assessment (LCA) with high-fidelity modeling for HRABPs, this study simulates productivity and removal efficiencies under realistic climatological conditions, providing life cycle inventories for numerous large-scale scenarios. To minimize environmental impacts while maximizing algal productivity and nitrogen intake in the algal biomass, 36 scenarios were simulated, considering different HRT, SRT, alkalinity addition, winter storage, and biomass post-treatment hypotheses. The results demonstrate that microalgae treatment makes sense for valorizing liquid digestate, proving to be less impactful than direct land application. However, the LCA results also highlight the complexity of the issue. Low HRT (HRT = 5 days < SRT = 10 days), including winter storage, requires the smallest production area, resulting in high productivity and low environmental impacts. Conversely, high HRT (HRT = 90 days > > SRT = 15 days) achieves the highest efficiency in nitrogen and phosphorus recycling but necessitates large production areas, leading to high environmental impacts. Mathematical modeling, coupled with LCA, can resolve these trade-offs and guide the optimization and scaling-up of climatology-dependent systems. PU - WILEY PI - HOBOKEN PA - 111 RIVER ST, HOBOKEN 07030-5774, NJ USA		
44	de Melo, C.V. and Albertini, T.G. and Bottene, A.C. and Guzzo, D.G.	2025	Proposal of a design tool combining performance criteria and circularity potential-A flexible film packaging application	Procedia CIRP	The increasing production of plastic worldwide requires different alternatives to prevent this material from polluting the planet. Flexible polymeric packaging, for food applications holds a significant share, mainly due to the associated linear usage cycle. Therefore, developing new products with the potential for circularity is a goal of suppliers in this important supply chain. This paper proposes a packaging design methodology that considers performance criteria and the circularity potential of the final product in its conceptual phase. The developed tool combines the material selection methodology proposed by Ashby [8] and the circularity indicator MCI [7], proposed by Ellen MacArthur Foundation. The result is a decision flowchart, consisting of the stages: gathering packaging requirements (mechanical and protection), selecting materials that meet the requirements, constructing the matrix of possibilities, proposing packaging concepts, evaluating circularity potential, and ranking according to cost criteria. The tool was evaluated using a case study methodology, conducted in partnership with a representative company of the flexible packaging supply chain. Thus, technical and processing decision attributes were included in the flowchart, bringing industrial contributions to this design tool and proving the feasibility of its use in the development process of new packaging for food applications. © 2025 Elsevier B.V.. All rights reserved.	barrier materials;circular economy;Circularity;design;MCI;packaging;Circular economy;Packaging materials;Product design;Supply chains;Barrier material;Circularity;Design tool;Flexible films;Food applications;MCI;Packaging applications;Packaging for foods;Performance criterion;Packaging	10.1016/j.procir.2024.12.009
45	Rasines, L. and San Miguel, G. and Corona, B. and Aguayo, E.	2024	Addressing the circularity and sustainability of different single-use and reusable crates used for fresh fruit and vegetables	Food Packaging and Shelf Life	This study assesses the sustainability of single-use (cardboard and wooden) crates and reusable plastic crates (RPC) from three perspective life cycle assessment (LCA), life cycle costing (LCC) and circular indicators: Material Circular Indicator (MCI), Material Reutilisation Score (MRS), and Circular Index (CI). A cradle-to-grave life cycle approach was applied to transporting 1 kg of fresh fruit or vegetables to the retailer point. The base case assumed single use for cardboard and wooden crates and 140 rotations for RPC. An optimised scenario was also assessed for RPC, assuming full recycling at its end-of-life. LCA, LCC, and circular indicators (MCI and CI) results indicated that RPC was the most sustainable and circular packaging. Increasing RPC recyclability to 100 % improved circularity scores, however its environmental impact slight increased. These results reflect that the food industry should adopt RPC use because of their higher economic, environmental performance, and circularity. © 2024 The Authors	Circular economy;Circularity indicator;Life Cycle Assessment;Life Cycle Costing;Micro scale;Packaging waste	10.1016/j.fpsl.2024.101391

			packaging				
46	Hidalgo-Crespo, J. and Rivas-García, P. and García-Balandrán, E.E. and Albalate-Ramírez, A. and Quintero-Herrera, S. and Velastegui-Montoya, A. and Amaya-Rivas, J.L. and Soto, M.	2024	Validating Circular End-of-Life Strategies for Domestic Post-Consumer Materials in the Latin American Region: A Life Cycle Assessment Approach	Environments - MDPI	This study examines the domestic solid waste management system in the LATAM region, using the city of Guayaquil in Ecuador as a case study. Through the life cycle assessment (LCA) methodology, the study compares domestic and external recycling processes, evaluating their effects on global warming potential, fossil resource scarcity, and terrestrial ecotoxicity. The results reveal that increasing recycling rates significantly reduces environmental impacts, with domestic recycling offering slightly higher environmental benefits than external options. A demographic analysis using machine learning techniques identifies distinct patterns of waste generation across different population clusters, highlighting the need for tailored waste management strategies. The study also emphasizes the importance of accurate local data and the integration of recycling initiatives with market realities, particularly in the light of policies mandating recycled content in products like PET bottles. A sensitivity analysis of the waste recovery indicator (WRI) demonstrates the potential for substantial environmental and economic benefits with higher recycling rates. The findings suggest that, to advance towards a circular economy, Latin American cities like Guayaquil must enhance their recycling infrastructure, refine waste management policies, and focus on demographic-specific strategies. This research contributes to the broader understanding of sustainable waste management in developing regions, offering insights for future policy and infrastructure development. © 2024 by the authors.	clustering and correlations functions;domestic;glass;life cycle assessment;metal;paper and cardboard;plastic;recycling scenarios;textile;waste recovery	10.3390/environments11110228
47	Zhang, Y. and Summers, S. and Jones, J.W. and Reid, J.F.	2024	A scalable index for quantifying circularity of bioeconomy systems	Resources, Conservation and Recycling	Increasing resource demands and efforts to mitigate anthropogenic impacts have thrust circular bioeconomy into the spotlight. However, there currently lacks a metric to provide singular quantification of circularity. This study showed development of a Circularity Index (CI) with value between 0 (completely linear) and 1 (completely circular) to quantify circularity of resource flows at different system scales, identify weak links in value-chains, and determine tradeoffs in the system. This study describes 1) CI for systems containing consumable, renewable, and recovered resources; 2) CI application for two examples: nitrogen in a corn-soybean farm and energy in the U.S. food and agricultural system. CI showed that nitrogen circularity increased from 0.687 to 0.860 through implementation of renewable fertilizer from manure compared to synthetic fertilizer. CI also demonstrated improved energy circularity in the U.S. food and agricultural system, increasing from 0.179 to 0.843 when integrating food-energy-water systems via hydrothermal liquefaction and nutrient recycling. © 2024 Elsevier B.V.	Energy;Food and agriculture;Indicator;Resource recovery;Valorization;Farms;Fertilizers;Agricultural system;Anthropogenic impacts;Energy;Food and agriculture;Food system;Resource demands;Resource flows;Resource recovery;Valorisation;Weakest links;Water recycling;ammonium nitrate;biogas;endocrine disruptor;fertilizer;gasoline;hemicellulose;nitrogen;anthropogenic effect;farming system;maize;soybean;valorization;agricultural waste;agricultural worker;Agrobacterium tumefaciens;anaerobic digestion;Article;Bacteroidetes;bioeconomy system;biomass;carbon cycle;climate change;economic aspect;eutrophication;food waste;freshwater environment;greenhouse effect;liquefaction;lymphocyt	10.1016/j.resconrec.2024.107821

						e count;manure;metastasis;municipal solid waste;nitrogen balance;nitrogen cycle;non-renewable resource;nonhuman;photosynthesis;phylogeny;pyrolysis;recycling;renewable resource;right coronary artery;soil analysis;telecommunication;waste management;water cycle;United States	
48	Gonçalves, M. and Freire, F. and Garcia, R.	2024	Material flow analysis and circularity assessment of plastic packaging: An application to Portugal	Resources, Conservation and Recycling	Material flow analysis (MFA) has been used to investigate plastic flows, albeit with limitations in providing a comprehensive assessment. This article proposes an MFA-based approach to assess circularity and presents an application to plastic packaging in Portugal, assessing flows (from polymer production to post-consumption treatment), calculating circularity indicators with different scopes, and analyzing circular economy scenarios. Results show that plastic packaging has a low circularity due to short lifespans and low recycling rates. The recycled input rate indicates an 11 % contribution of recycled materials in reducing the use of virgin materials. The circular economy scenarios analyzed show that meeting the European Plastics Pact targets for 2025 is theoretically viable; however, achieving them requires ambitious enhancements, such as improvements in recyclability and incorporating more recycled materials towards a more circular plastic packaging system. The MFA-based approach proposed can be applied to other products and materials. © 2024 The Author(s)	Circular economy;Circularity indicators;Material flow analysis (MFA);Plastic packaging;Waste Management;Elastomers;Packaging;Packaging materials;Plastic products;Plastic recycling;Analysis-based approaches;Circular economy;Circularity indicator;Comprehensive assessment;Material flow analyse;Materials flow analysis;Plastic packaging;Polymer production;Portugal;Recycled materials;Waste management;plastic;polyethylene;polyethylene terephthalate;polymer;polystyrene;material flow analysis;waste management;agricultural worker;anaerobic digestion;Article;bioremediation;chemical oxygen demand;consumption-based indicator;drug marketing;economic aspect;flow measurement;geographical variation (species);growth rate;human;information processing;landfill;life cycle;mathematical analysis;municipal solid waste;packaging;poultry;recycling;reliability;solid waste management	10.1016/j.resconrec.2024.107795

49	Preuss, N. and You, F.	2024	Consequential versus attributional life cycle optimization of poultry manure management technologies in a food-energy-water-waste nexus	Journal of Cleaner Production	To model the environmental and economic tradeoffs of managing poultry manure wastes in a food-energy-water-waste nexus, this work builds a framework to conduct a combined life cycle and techno-economic optimization and a spatial analysis of poultry manure management technologies. To align with the United Nations Sustainable Development Goals 6: Clean Water and Sanitation and 13: Climate Action by mitigating the massive water and climate impacts induced by the common practice of fertilizer crops using direct land application of poultry manure, the framework minimizes freshwater eutrophication (FE) impact and climate change impact (GWP). To account for the circular economy, the net present value (NPV) is maximized to measure the economic feasibility of implementing alternative management pathways. A multi-objective mixed-integer non-linear programming framework accounts for the selection of direct land application, and waste to energy technologies, spatial variation in manure supply, facility sizing, and the products' consumption and end-of-life. This optimization framework is evaluated for a case study in New York state. Under an attributional life cycle optimization, anaerobic digestion minimizes FE with an impact of 0.002 kg P-eq/ton manure, while using a consequential life cycle optimization, hydrothermal carbonization minimizes FE with an impact of −0.96 kg P-eq/ton manure. For both life cycle methodologies, pyrolysis with land application of biochar minimizes GWP. At the attributional life cycle assessment tradeoff point for GWP and NPV, minimum carbon credits of US$33/ton CO<inf>2</inf>-eq are necessary for a pyrolysis plant to have a positive NPV, implying that harnessing economies of scale or robust carbon accounting is necessary for the widespread adoption of pyrolysis as a poultry manure management technology. © 2024 Elsevier Ltd	Food-energy-water-waste nexus;Life cycle assessment;Poultry manure;Sustainability;Waste to energy technologies;Anaerobic digestion;Carbon;Carbonization;Climate change;Economic analysis;Environmental technology;Eutrophication;Fertilizers;Integer programming;Manures;Nonlinear programming;Pyrolysis;Sustainable development;Energy;Food-energy-water-waste nexus;Land applications;Life cycle assessment;Management technologies;Manure management;Optimisations;Poultry manure;Waste-to-energy technologies;Water wastes;Life cycle	10.1016/j.jclepro.2024.143133
50	Larasati, K. and Frimawaty, E. and Chairani, E.	2024	LIFE CYCLE ASSESSMENT OF PLASTIC PACKAGING PRODUCTION	Journal of Environmental Science and Sustainable Development	The plastic packaging industry has become a significant commodity that penetrates almost every aspect of our lives, requiring greater responsibility from the industry for the life cycle management of their products. Several study methodologies are available to measure the industry's environmental impact, with life cycle analysis (LCA) gaining traction in Indonesia. Therefore, this study aims to measure the environmental impact of the plastic packaging industry analyzed using LCA with a focus on the main potential impact categories of global warming, acidification of the earth, toxicity to humans, formation of photochemical oxidants, and fossil depletion, within the scope of cradle to gate which was analyzed using SimaPro software. This research compares with previous research conducted in several countries (such as Poland, Qatar, and France) that conducted LCA on the plastic packaging industry. The results from Bogor, West Java, Indonesia, showed that the increase in the amount of plastic packaging produced contributes to environmental impact. Comparative studies reveal that the environmental impact is influenced by factors such as the quantity of recycled materials, the number of circularity cycles, and waste management strategies. Future LCA studies should also aim to refine inventory data, delving into greater detail for each unit of the process. This will yield more precise insights into the overall environmental impact of the process. © 2024, School of Environmental Science, Universitas Indonesia. All rights reserved.	Environmental impact;LCA;Manufacturing;Plastic packaging	10.7454/jessd.v7i1.1220
51	Pinto, S.M. and Gouveia, J.R. and Sousa, M. and Rodrigues, B. and Oliveira, J. and Pinto, C. and	2024	Improving coffee capsules recyclability - A combined assessment of circularity and environm	Sustainable Production and Consumption	Coffee capsules have gained high levels of popularity in the last decades due to their convenience of use, flavour choices, and consistent extraction quality. As governmental bodies are promoting more circular solutions for packaging products, concerns have been raised regarding the environmental impacts of single-use coffee capsules, namely their end-of-life treatment and effective recyclability. This paper presents a novel design based on thin steel sheet material application for new packaging solutions that can support a more circular economy. To validate this new design, a framework was presented for a cross-assessment of Life Cycle Assessment with Circularity Analysis to compare the new tinplate capsule with conventional polypropylene and aluminium capsules. The novel design is more circular (0.97 in the material circularity indicator), in comparison	Circular economy;Circularity;Coffee capsules;End-of-life recyclability;Environmental performance;Life Cycle Assessment;Sustainable consumption;Aluminum;Environmental impact;Environmental management;Polypropylenes;Steelmaking;Circular	10.1016/j.spc.2024.02.025

	Baptista, A.J.		ental performance of a novel design		with the polypropylene (0.1) and aluminium (0.80) conventional capsules, due to the ferromagnetic properties that allow for better effectiveness during sorting in urban packaging recycling facilities. As for the environmental assessment, the tinplate has higher environmental impacts than the aluminium and the polypropylene capsules (more 63 % and more 92 %, respectively) due to the high energy intensity processes required to produce this material. These results demonstrate that the novel tinplate capsule should complement the strong results in circularity with further improvements in its environmental performance, namely by the transition of the steel industry to the upcoming generation of decarbonized steel production. © 2023	economy;Circularity;Coffee capsule;End of lives;End-of-life recyclability;Environmental performance;Life cycle assessment;Novel design;Recyclability;Sustainable consumption;Life cycle	
52	Desole, M.P. and Gisario, A. and Fedele, L. and Aversa, C. and Barletta, M.	2024	Life cycle assessment of secondary packaging: Expanded polystyrene versus bioplastic-coated corrugated cardboard	Sustainable Production and Consumption	Recent European regulations have imposed ecological alternatives to the packaging of expanded polystyrene (EPS) dairy products. In this study we explore the opportunity to replace the expanded polystyrene packaging, with a corrugated cardboard coated with bioplastic for the storage and transport of cheese and mozzarella. Life cycle analysis (LCA) indicates that the use of bioplastic coated corrugated board could significantly reduce the packaging's carbon footprint. Corrugated board has a lower environmental impact than polystyrene, except for the ecosystem quality indicator. This indicator is worse for corrugated because of the impacts associated with the cultivation of corn and sugar cane needed for bioplastics production, as well as the deforestation associated with paper production. EPS, on the other hand, is more impactful due to oil extraction and disposal processes such as landfill and incineration. From the analysis of defined sensitivity by increasing the percentage of composting and recycling, there is an improvement in the environmental performance of coated board, even in critical categories. Therefore, the latter scenario is the ideal and desired solution to obtain the replacement of EPS packaging with bioplastic coated cardboard. © 2024 The Author(s)	Circular economy indices;Corrugated cardboard;Life cycle analysis;Polystyrene;Sensitivity analysis;Carbon footprint;Environmental management;Incineration;Life cycle;Packaging;Polypropylenes;Polystyrenes;Reinforced plastics;Sugar cane;Wood products;Bio-plastics;Circular economy;Circular economy index;Corrugated boards;Corrugated cardboards;Economy index;European regulation;Expanded polystyrene;Life cycle analysis;Secondary packaging;Sensitivity analysis;Combustion;Corrugated Boards;Life Cycle;Sugar Cane;Wood Products	10.1016/j.spc.2024.02.010
53	Sazdovski, I. and Batlle-Bayer, L. and Bala, A. and Margallo, M. and Azarkamand, S. and Aldaco, R. and Fullana–i–Palmer, P.	2024	Comparative assessment of two circularity indicators for the case of reusable versus single-use secondary packages for fresh foods in Spain	Heliyon	Sustainable packaging is a crucial focus in the context of circular economy efforts. This study evaluates the circularity of two secondary packaging systems used in Spanish fresh food produces: Reusable Plastic Crates and Single-use Cardboard Boxes. A Mass Flow Analysis was performed to assess the material flows in the production and use phases of both systems and two circular indicators were applied: the Material Circularity Indicator and Product Circular Indicator. While most previous studies for single-use packaging use these indicators at the product level, this study applies a system approach since the Reusable Plastic Crates can be reused 100 times. The functional unit was defined as the distribution of 1000 tonnes of fresh products, resulting in the distribution of 6,666,700 packages with 15 kg of products. The Material Circularity Indicator and Product Circular Indicator results show that Reusable Plastic Crates are more circular than Single-use Cardboard Boxes. The Product Circular Indicator provides a more comprehensive assessment of circularity by considering multiple life cycle stages, efficiency, and unrecoverable waste, resulting in a difference in circularity evaluations. The indicators used have limitations as they do not consider the resource stock. Further research is needed to explore this aspect. © 2024 The Authors	Circular economy;Circularity indicators;LCA;Reusable plastic crates;Supply chain;Sustainable packaging	10.1016/j.heliyon.2024.e27922

54	Matos, J. and Martins, C.I. and Simoes, R.	2024	Circularity Micro-Indicators for Plastic Packaging and Their Relation to Circular Economy Principles and Design Tools	Sustainability (Switzerland)	Plastic packaging, in the form of films, brought several advantages to the commercialization of products given its lightness and durability. It provided better ergonomics, ease of transport, increased shelf life, and easy handling and use. Despite that, plastic packaging is facing enormous sustainability concerns associated with the traditional practice of linear economy, combined with commonplace irresponsible handling by citizens since it is almost exclusively designed for single-use and its end-of-life (EOL) management is not planned for. To mitigate that, the circularity of plastic packaging must be more clearly studied and evaluated through approaches such as micro-level circular economy (CE) indicators. This paper focuses on the selection of relevant CE micro-indicators specifically for the plastic packaging sector among the plethora of indicators available. Relations are also established between CE micro-indicators and CE guiding principles, as well as the most prevalent Design for X (DfX) approaches, providing new insights into how these different aspects of sustainability can be linked together. Results show three micro-level indicators as the most relevant for circularity calculation in packaging, namely those termed 'MCI', 'VRE', and 'CEIP', because their methodology and approach address most of the CE guiding principles and DfX approaches relevant for the packaging sector. Finally, guidelines and good practices to promote circularity adoption in the plastic packaging sector are highlighted. This work can guide companies aiming to adopt CE micro-indicators in their practical implementation, overcoming the significant knowledge barrier that currently exists. © 2024 by the authors.	CE guiding principles;circular economy;circularity indicators;Design for X;packaging;plastics;commercialization;design;economic activity;plastic;sustainability	10.3390/su16052182
55	Thomassen, G. and Peeters, E. and Van Hee, N. and Noëth, E. and Du Bois, E. and Boone, L. and Compernolle, T.	2024	The environmental impacts of reusable rice packaging: An extended comparative life cycle assessment	Sustainable Production and Consumption	Plastic packaging recycling has gained momentum as it can improve the circularity of this typical linear product. However, reuse ranks as a preferred strategy over recycling because product reuse can reduce material usage compared to product recycling and keeps material value higher for a longer time. Such reusable plastic packaging requires, besides a more robust product design, an additional return system. It is crucial to minimize the impact of this product system and ensure that reusable plastic packaging is not only more circular, but also more environmentally friendly than its single-use alternative. For this purpose, understanding the factors contributing to its environmental impact is key. In this paper, a new design of reusable packaging for two kilogram rice is compared with a conventional fully-optimized single-use packaging using a prospective extended life cycle assessment, including a circularity (using material flow analysis and specific circularity indicators, among which the Material Circularity Index), environmental impact (using a life cycle assessment with 16 midpoint indicators) and packaging-related food losses and waste assessment (using the food-to-packaging ratios). On average, the reusable rice packaging could be reused five times, due to losses at the distribution, use, and reuse preparation phase. While the reusable packaging scores better on the circularity indicators (a Material Circularity Index of 91 %, compared with 39 % for single-use packaging), its global warming and fossil resource depletion impact are respectively two and three times higher, considering a functional unit of one kilogram cooked rice to be consumed. The reusability and return rate, providing the retention of reusable packaging at the reuse preparation and use phase, respectively, were identified as the most determinative parameters by the sensitivity analysis. If these parameters could be optimized to a value of 99.75 %, corresponding to a total of 16 uses, the climate change impact of reusable packaging would be lower than its conventional single-use counterpart. The high food-to-packaging ratios (more than 18 for all impact categories) point to the importance of reducing food waste. If the packaging design could reduce food losses in the product system with 0.2 %, the reusable packaged rice would have a lower water use and mineral and metal resource use impact compared to the single-use packaged rice, despite the higher environmental impact of the reusable packaging unit itself. Therefore, this should be prioritized	Circular economy;Environmental impact assessment;Material flow analysis;Plastic packaging;Reuse;Sustainable design;Carbon footprint;Environmental impact assessments;Global warming;Life cycle;Packaging;Packaging materials;Product design;Recycling;Reusability;Sensitivity analysis;Sustainable development;Circular economy;Food loss;Food waste;Materials flow analysis;Plastic packaging;Preparation phasis;Product systems;Reusable packaging;Reuse;Single use;Ecodesign	10.1016/j.spc.2024.01.014

					when further optimizing the reusable packaging design. © 2024 Institution of Chemical Engineers		
56	Lara-Topete, G.O. and Castanier-Rivas, J.D. and Gradilla-Hernández, M.S. and González-López, M.E.	2024	Life cycle assessment of agave bagasse management strategies: PLA biocomposites versus conventional waste disposal practices	Sustainable Chemistry and Pharmacy	Tequila production is one of Mexico's largest agro-industries, generating significant amounts of agave bagasse (AB) as its primary solid waste. Current AB management practices encompass composting, open dumps, and incineration. Life cycle analysis was developed to compare the environmental impact of these management scenarios with developing value-added agave fiber (AF) reinforced plastic biocomposites and generating biogas through anaerobic digestion. The assessment compares three molding methods for the PLA-AF biocomposite, with the environmental impact evaluated against pure PLA and low-density polyethylene (LDPE). Extrusion-injection molding was the most environmentally friendly molding method across all indicators, primarily due to the reduced inputs required for pretreating the fibers. Among the current management scenarios, composting was the least environmentally impactful for the global warming potential indicator. Nonetheless, composting requires substantial time and land use, posing challenges for some producers. Incineration displayed a significant trade-off on the fossil resource scarcity indicator by replacing natural gas. Anaerobic digestion displayed high impacts in all indicators as AB does not yield high methane potential. While the production of PLA-AF displays a significantly higher environmental impact, it remains a preferable option when compared to pure PLA and may further improve its sustainability through green chemistry principles. Notably, LDPE was less environmentally impactful than both bioplastic options assessed, due to the environmental impacts of PLA production and the widespread standardization of LDPE production processes. Context-specificity is critical to assess the environmental impact of circular bioeconomy pathways, which are not always inherently beneficial, while addressing SDG 12: Responsible Consumption and Production. © 2024 Elsevier B.V.	Agave fibers;Biocomposites;Circular economy;Life cycle assessment;bagasse;biogas;fertilizer;low density polyethylene;methane;natural gas;plastic;polyethylene;unclassified drug;Agave;anaerobic digestion;Article;biocomposite;biodegradability;biofuel production;biomass production;centrifugation;composting;decomposition;dumping;energy recovery;environmental impact;gas;global warming potential;humification;incineration;land use;leaching;life cycle assessment;nonhuman;pine;pine needle;processing;shear rate;standardization;waste disposal;waste management	10.1016/j.scp.2024.101435
57	Anand, K. and Martínez-Arce, A. and Bishop, G. and Styles, D. and Fitzpatrick, C.	2024	A tasty solution to packaging waste? Life cycle assessment of edible coffee cups	Resources, Conservation and Recycling	Edible cups have been proposed as a solution to littering and plastic pollution arising from disposal of 500 billion beverage cups each year. We applied life cycle assessment and a littering indicator to benchmark the environmental performance of edible cups against mainstream cup types made from paper, polylactic acid (PLA), polystyrene (PS) and reusable cups made from polypropylene (PP) and steel. Various end-of-life treatment scenarios were analysed. Across most impact categories, edible cups incur the largest burdens, and reusable cups the smallest (if reused at least 54 times). Under default assumptions, per cup use, climate change burdens ranged from 0.004 to 0.1 kg CO<inf>2</inf> equivalent, eutrophication burdens ranged from 6.26 × 10–6 to 4.21 × 10–4 kg N, fossil resource depletion burdens ranged from 0.05 to 0.284 MJ and water depletion burdens ranged from 0.002 to 0.437 m3. However, if edible cups are eaten after use and substitute a similar snack then their use could incur negligible environmental impact. Furthermore, edible cups demonstrate low littering potential and thus could play a role in transition towards more sustainable coffee consumption. © 2023 The Author(s)	Beverage cup;Circular economy;Edible packaging;Environmental footprint;Littering;Benchmarking;Beverages;Climate change;Environmental impact;Environmental management;Eutrophication;Polypropylenes;Beverage cups;Circular economy;Edible packaging;End of life treatments;End-of-life treatments;Environmental footprints;Environmental performance;Littering;Packaging waste;Plastic pollutions;Life cycle;polylactic acid;polypropylene;polystyrene;steel;beverage;environmental impact;life cycle analysis;litter;packaging waste;recycling;sustainable development;waste management;Article;climate change;cocoa bean;coffee;coffee	10.1016/j.resconrec.2023.107320

						consumption;consumer;controlled study;economic aspect;edible packaging;environmental footprint;fossil;human;life cycle assessment;plastic pollution;plastic waste	
58	Mura, R. and Vicentini, F. and Botti, L.M. and Chiriacò, M.V.	2024	Achieving the circular economy through environmental policies: Packaging strategies for more sustainable business models in the wine industry	Business Strategy and the Environment	The environmental and economic benefits of adopting a circular economy (CE) approach could be significant for firms. The CE and packaging constitute a fundamental binomial for our economy, yet there are still few studies of the advantages for food value chains, especially in the wine sector. Therefore, in this paper, we address this research gap by measuring the environmental and economic performance of a circular business model (CBM) adopting the wine industry as a reference. We apply a combination of Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) methods to a small Italian winemaking firm, which implements a circular strategy through the take-back and refurbishment of wine packaging components. Results show that by implementing this sustainable and CBM, a firm can reduce greenhouse gas (GHG) emissions from 8 to 90% and save from 6 to 63% of its economic costs. © 2023 The Authors. Business Strategy and The Environment published by ERP Environment and John Wiley & Sons Ltd.	circular business models;circular economy;food impact;GHG;LCA;LCC;corporate social responsibility;environmental economics;environmental policy;greenhouse gas;life cycle analysis;numerical model;sustainability;wine industry;Italy	10.1002/bse.3556
59	Bukhonka, N.P. and Kyzymchuk, O.	2024	Circularity in Knitting: The Potential of Re-Using Natural Yarns After Unraveling	Journal of Natural Fibers	Currently, there is an increasing focus on sustainable textile manufacturing in terms of reducing the waste generated during the production and pre-consumer stages. Knitting companies are exploring the promising direction of unraveling and upcycling yarn to achieve this goal. To assess the knittability of unraveled yarn vis-a-vis conventional yarn, a comprehensive indicator of yarn-breaking force changes was proposed. The purpose of this study is to present a method to evaluate the strength property of unraveled yarn and to investigate the potential of 74-tex cotton and 72-tex wool yarn for future upcycling in knitting. The results of the investigation revealed that cotton yarn has a higher potential for upcycling both at pre- and post-consumer stages, compared to wool yarn. The knittability of unraveled cotton yarn is almost 99% after knitting and dry relaxation and over 95% after repeated washing and drying cycles. However, it is pertinent to note that repeated ironing impacts the cotton yarn's knittability, and hence, it is recommended to label future upcycling products with a special marking prohibiting ironing. The possibility of unraveling and reusing wool yarn is limited to the post-production and pre-consumer stages when its knittability is near 95%. © 2024 The Author(s). Published with license by Taylor & Francis Group, LLC.	breaking load;circularity in knitting;cotton yarn;Textile upcycling;wool yarn;yarn knittability;Cotton yarn;Textiles;Wool;Breaking force;Breaking load;Circularity in knitting;Knittability;Strength property;Sustainable textiles;Textile manufacturing;Textile upcycling;Wool yarns;Yarn knittability;Cotton;Knitting;Marking;Production;Relaxation;Yarn	10.1080/15440478.2024.2375517
60	Rossi, M. and Cappelletti, F. and Manuguerra, L. and Mundo, M. and Germani, M.	2024	Ecodesign Strategies for Packaging: A Simplified Approach to Evaluate Environ	Procedia CIRP	The improvement of environmental product performance is an important driver for product development. It is also related to the optimization of product packaging solutions. This paper addresses the question related to packaging eco-design strategies. A simplified approach, based on the Life Cycle Assessment methodology and Material Flow Analysis, is proposed to quickly compare alternative design solutions in terms of environmental impacts. Quantifying impacts and identifying the most significant design parameters for these products can assist industrial companies in avoiding potential impact transfer issues and finding the best solutions for their products. Multiple environmental impact categories and indicators are included to comprehensively consider impacts on the environment, resources, and human health. The proposed approach is applied to the environmental performance evaluation of several alternative design solutions for the packaging of a professional coffee machine. Alternative designs, starting	Circular economy;Ecodesign;Environmental sustainability;Packaging;Environmental impact;Environmental management;Life cycle;Packaging;Product design;Supply chains;Sustainable development;Alternative designs;Circular economy;Design	10.1016/j.procir.2024.01.049

			mental Benefits		from the selection of appropriate materials to the identification of solutions suitable for the reverse supply chain, will be compared and deeply analysed in environmental terms. © 2024 Elsevier B.V.. All rights reserved.	solutions;Ecodesign strategies;Environmental benefits;Environmental products;Environmental sustainability;Optimisations; Product packaging;Product performance;Ecodesign	
61	Corona, B. and Tunn, V.S.C. and van den Broek, K.L.	2024	Integrating consumer behaviour into the environmental assessment of circular packaging: a scoping review	International Journal of Life Cycle Assessment	Purpose: The impact of applying circular strategies to products is often measured through life cycle assessment (LCA). While LCA estimates and compares the impacts of circular products, its ability to integrate consumer behaviour is currently limited. The integration of consumer behavioural insights is especially relevant in the packaging sector, where consumer actions at the end-of-life are crucial for the success of circular strategies. This study explores integrating behavioural insights from consumer behaviour sciences (including psychology, sociology and socio-technical approaches) into LCA for a better assessment and design of circular packaging. Methods: Through a scoping review, scientific literature was mapped to (1) investigate the current integration of consumer behaviour aspects within packaging LCAs and (2) explore the behavioural determinants influencing the recycling and reusing of circular packaging. By building on the insights from these reviews, this study provides recommendations on how to integrate behavioural insights with LCA to assess the impact of circular packaging systems. Results and discussion: The results indicate that LCA studies for packaging are generally based on assumptions on consumer behaviour, reducing their utility for circular decision-making. The main methods currently used to integrate behaviour variability are scenario and sensitivity analysis, with some studies using consumer profiles and behaviour research to support LCA modelling. Socio-technical approaches, e.g. agent-based modelling or system dynamics, have not been applied yet to integrate a behavioural perspective into the LCA of circular packaging, while this may be a promising avenue. The behaviour science literature covered several predictors found to be important to understand packaging reuse and recycling behaviour. Our review shows that attitudinal and value dimensions have consistently been found to influence both packaging reuse and recycling behaviour, while the latter is also strongly driven by control factors. While LCA modellers can obtain behavioural insights from the behavioural literature, the step of transforming these insights into quantifiable behaviour patterns still needs to be taken. Such endeavours can help to translate individual behaviour predictors into behavioural patterns regarding packaging reuse and recycling. Conclusions: Consumer behaviour is currently not widely considered in the LCA of circular packaging. Insights from consumer behaviour sciences can contribute to LCA studies in two main ways: defining consumer profiles and modelling socio-technical parameters. Consumer profiles could be drawn from the psychological behaviour literature, while socio-technical approaches can provide models of system behaviour where the interaction of different system actors and items is quantitatively modelled and coupled with LCA models. © 2023, The Author(s).	Behaviour pattern;Circular economy;Consumer profiles;Life cycle assessment;Recycle;Reuse;behavioral science;consumer attitude;decision making;economic aspect;human;life cycle assessment;psychology;quantitative analysis;recycling;review;scientific literature;sensitivity analysis;sociology	10.1007/s11367-023-02218-1
62	D'Imporzano, G. and Adani, F.	2023	Measuring the environmental impacts of sewage sludge use in agricultur	Science of the Total Environment	This study compares two scenarios for sewage sludge treatment i.e., agricultural-land application (LA) and incineration (INC), in an Italian context (Pavia province, Po Valley). The study was realised within a regional project aiming to obtain useful data to better address future sludge management policies. To do so, an attributional Life Cycle Assessment (LCA) approach was chosen and the multi-functionality was addressed by using system expansion. Results indicated that the scenario INC had higher impacts than scenario LA for the categories linked to process inputs and to the direct emissions of incineration, such as Global warming potential (= + 60 %)., Stratospheric Ozone Depletion, Ozone Formation, Mineral Resource Scarcity and Fossil Resource Scarcity. System expansion i.e., the	Circular economy;Environmental impacts;Incineration;Life Cycle Assessment (LCA);Recovered fertilisers;Sewage sludge;Cell proliferation;Eutrophication; Expansion;Global warming;Life cycle;Mineral	10.1016/j.scitotenv.2023.167025

			e in comparison with the incineration alternative		production of non-renewable fertilisers, played a large role (higher impacts) in the categories related to resource scarcity in the INC scenario. On the other hand, LA scenario showed higher impacts than INC for direct emissions due to fertilisation (Marine and Freshwater Eutrophication, and Particulate Matter). In conclusion, the use of sewage sludge in agriculture seemed to be competitive with the alternative of incineration but both sludge quality and emission reduction during sludge distribution in the field play an important role in the reduction of environmental impacts. © 2023 Elsevier B.V.	resources;Ozone;Ozone layer;Sewage sludge;Agricultural land application;Circular economy;Direct emissions;High impact;Land applications;Life cycle assessment;Recovered fertilizer;Resource scarcity;Sewage sludge treatment;System expansion;Fertilizers;agriculture;environmental impact;incineration;life cycle analysis;sewage;sludge;waste management;agricultural land;agricultural procedures;Article;comparative study;eutrophication;fertilizer application;fossil resource scarcity;freshwater eutrophication;global warming potential;Italy;life cycle assessment;marine eutrophication;mineral resource scarcity;ozone depletion;ozone formation;ozone layer;particulate matter;sludge treatment	
63	Bhambhani, A. and Kapelan, Z. and van der Hoek, J.P.	2023	A new approach to circularity assessment for a sustainable water sector: Accounting for environmental functional flows and losses	Science of the Total Environment	Resource recovery solutions can reduce the water sector's resource use intensity. With many such solutions being proposed, an assessment method for effective decision-making is needed. The water sector predominantly deals with biogeochemical resources (e.g., nitrogen) that are different from technical resources (e.g., industrial coagulants) in three ways: (1) they move through the environment in natural cycles; (2) they fulfil different human and environmental functions; and (3) they are subject to substantial environmental losses. Whilst several circularity assessment methods exist for technical resources, biogeochemical resources have received less attention. To address this, a well-established material circularity indicator (MCI) method is modified. This is done by redefining the terms: restoration, regeneration, and linear flows to create a new circularity assessment approach. The new approach is demonstrated in a real-life case study involving treated wastewater (TW) fertigation. The new approach reveals that using the original MCI method underestimates the circularity of resource recovery solutions involving biogeochemical resources. This is because, in the original MCI method, only the flows that are reused/recycled for human functions can be considered circular, whereas, in the new approach, one also considers flows such as N<inf>2</inf> emission and groundwater infiltration as circular flows. Even though these may not be reuse/recycle type flows, they still contribute towards future resource availability and, thus, towards sustainability. The modified assessment method shows that TW fertigation can significantly improve nitrogen and water circularity. However, careful planning of the fertigation schedule is essential since increasing fertigation frequency leads to lower water but higher nitrogen circularity. Additionally, collecting drainage water	Biogeochemical resources;Circularity assessment;Fertigation;Resource recovery;Wastewater reuse;Biogeochemistry;Decision making;Groundwater;Sustainable development;Wastewater reclamation;Wastewater treatment;Water conservation;Biogeochemical resource;Biogeochemicals;Circularity assessment;Fertigations;Indicator methods;New approaches;Resource recovery;Technical resources;Wastewater reuse;Water sector;Nitrogen;groundwater;nitrogen;biogeochemical cycle;environmental assessment;fertilizer	10.1016/j.scitotenv.2023.166520

					for reuse can improve nitrogen circularity. In conclusion, using the modified MCI approach, circularity can be assessed in a manner that is better aligned with sustainability. © 2023 The Authors	application;resource use;wastewater;water industry;Article;case study;environmental monitoring;fertigation;nitrogen utilization;recycling;wastewater management;water analysis;water flow	
64	Rodino, S. and Pop, R. and Sterie, C. and Giucă, A. and Dumitru, E.	2023	Developing an Evaluation Framework for Circular Agriculture: A Pathway to Sustainable Farming	Agriculture (Switzerland)	This article examines how circularity can be measured and evaluated in the agricultural sector. Circularity represents a key approach for promoting sustainability in agriculture and for the efficient management of resources. Through a comprehensive review of the scientific literature and employing rigorous selection methods, we identify the relevant indicators and tools for assessing circularity in the agri-food chain. The initial bibliometric analysis was performed by using a Biblioshiny instrument from R package tool Bibliometrics. Additionally, this article analyzes the methodologies based on the indicators and metrics that can be applied to measure the restorative capacity and effectiveness of the agricultural system. Most current research follows the 3R principles of the circular economy and establishes an evaluation index system based on the regional characteristics. Methods such as the multi-criteria decision analysis, data envelopment analysis, and life cycle assessment are the most used to date. For the micro-level analysis, system dynamics, material flow analysis, and emergy analysis were the most suitable. Our results provide a clear perspective on the current state of the research in the field of measuring circularity in agriculture and lay the groundwork for the future development of effective strategies for implementing the circular economy in this crucial sector. © 2023 by the authors.	agriculture;circular economy;metrics	10.3390/agriculture13112047
65	Lavallais, C.M. and Dunn, J.B.	2023	Developing product level indicators to advance the nitrogen circular economy	Resources, Conservation and Recycling	Increasingly, circularity indicators for material, energy, and water systems guide circular economy design. While indicators for products made from recycled carbon-based materials are somewhat common, peer indicators for waste nitrogen-derived products are limited. It is important, however, to develop such indicators to guide emerging technologies that transform waste nitrogen into products. In this study, we summarize the nitrogen circularity indicator literature, emphasizing the agricultural and wastewater sectors. Next, we use the Material Circularity Indicator (MCI) developed by the Ellen MacArthur Foundation, to quantify the circularity of products made from waste nitrogen in swine manure. We considered four test cases using different technologies to recover nitrogen from the manure. Our analysis indicates that technologies that seem to increase circularity on the surface may not yield a substantial increase in MCI results. Finally, we discuss the strengths and weaknesses of using the MCI for product-level analysis and further developments. © 2023	Circular economy;Indicators;Nitrogen;Fertilizers;Manures;Carbon based materials;Circular economy;Derived products;Developing product;Emerging technologies;Energy and water systems;Further development;Material systems;Swine manure;Test case;Nitrogen;carbon;nitrogen;industrial waste;recycling;sustainability;waste technology;agricultural management;Article;circular economy;controlled study;economic aspect;life cycle assessment;nitrogen utilization;nonhuman;quantitative analysis;surface property;swine manure;technology;wastewater;water supply	10.1016/j.resconrec.2023.107167
66	Le, T.N.Q. and Robertson, K. and	2023	Microflow synthesis of a	Green Chemistry	Highly soluble commercial phosphorus (P) fertilisers have been the most common form of P applied in agriculture for decades, but their releasing efficiency can be low because phosphate ions can easily bind with cations in the soil to form precipitates or highly water-soluble species, leaching into nearby water sources	Calcium phosphate;Chitosan;Efficiency;Eutrophication;Fertilizers;Ions;Soil conservation;Soil	10.1039/d3gc02859c

	Escribà-Gelonch, M. and Marschner, P. and Tran, N.N. and Williams, P.M. and Fisk, I. and Hessel, V.		formulation of phosphorus fertiliser to enhance the P content in soil and P uptake in wheat		and thus causing eutrophication. Using a coiled flow inverter (CFI), a new formulation of phosphorus fertiliser was prepared containing three main components: a solid P source (biphasic calcium phosphate), a soil remediation agent (citrate ions) and a binding agent (chitosan). Our study is the first to assess the fertiliser performance of a material made in flow that is a finished product exhibiting structural and functional complexity, and we have also demonstrated its performance by soil experiments. We provide a proof of concept at scale of this complex product, which may indicate its potential for commercial application. The key factors used to evaluate the prepared fertiliser were the P-releasing efficiency, soil-available P and P uptake. In the incubation experiment, the available P in soil applied with the prepared formulation was three times higher than soil applied with commercial apatite (probability value, p-value < 0.05) and was as high as soil applied with commercial P fertiliser. After incubating for 14 days, 63% of the applied P in the prepared fertiliser was released into the soil. The formulation without chitosan exhibited a higher uptake of P in Scepter wheat in comparison with phosphate rock. In the soil-column experiment, the commercial P fertiliser leaked double the amount of phosphorus after 23 days and had a fluctuated releasing behaviour when compared with the prepared formulation. Its batch synthesis and flow synthesis (8 mL min−1) shared similar green chemistry metrics, including an E-factor of 0.4 kg kg−1. Continuous-flow production for CS-ACP-Cit showed a higher productivity than the batch production by a factor of 1.9. The circularity of the process, denoted by the Materials Circularity Indicator (MCI), while considering experimental recycling data, was high for all the process steps and composites, scoring in the range of 0.8, which was interesting, considering that this was a non-optimised process. The circularity assessment took account of the performance of the composites, which is expressed as the intensity factor (U; performance) and lifetime (L) of the MCI. © 2023 The Royal Society of Chemistry.	pollution;Biphasic calcium phosphates;Flow inverters;Micro-flow;P contents;P fertilizers;Performance;Phosphate ions;Phosphorus fertilizer;Water source;Water-soluble species;Soils	
67	Chaudhari, U.S. and Kulas, D.G. and Peralta, A. and Hossain, T. and Johnson, A.T. and Hartley, D.S. and Handler, R.M. and Reck, B.K. and Thompson, V.S. and Watkins, D.W. and Shonnard, D.R.	2023	Solvent based dissolution-precipitation of waste polyethylene terephthalate: economic and environmental performance metrics	RSC Sustainability	Polyethylene terephthalate (PET) is one of the highest production volume polymer resins, with wide ranging applications in consumer packaging. Due to challenges in closed-loop recycling of PET, recycle rates in the U.S. are low (13% compared to PET resin converted), with the vast majority landfilled or leaked to the environment at the end of life. Solvent based dissolution and precipitation recycling technology has the potential to achieve closed-loop recycling of PET in food packaging and help achieve a circular economy for plastics. However, this technology is still in the early stages of development and there is an urgent need to understand the economic costs and environmental impacts to select promising process pathways. In this study, we analyze three precipitation process configurations for production of high-quality PET resin from post-consumer waste PET using gamma-valerolactone as the solvent: (i) anti-solvent using water, (ii) solvent evaporation, and (iii) cooling of the dissolved polymer solution. The process conditions and yields were obtained from literature sources, and process simulation was employed to estimate energy consumption and process economics. Using standard chemical engineering techno-economic analysis (TEA) assumptions and current market prices, the anti-solvent process was found to be the least profitable compared to evaporation or cooling precipitation methods, although all exhibited positive net present values. The environmental life cycle assessment (LCA) results revealed that the anti-solvent process produced 60% higher greenhouse gas (GHG) emissions compared to fossil virgin PET, but the evaporation and cooling processes reduced GHG emissions by about 50%. The sensitivity of the results to process and recycling system parameters were thoroughly investigated. © 2023 RSC.		10.1039/d3su00231d
68	Vlasopoulos, A. and Malinauskai	2023	Life cycle assessme	Energy	Plastics are essential in our economy and everyday life. However, plastic pollution is a global concern. To address this issue, the European Strategy for Plastics in a Circular Economy was adopted in January 2018. Attention has been raised to the	Energy recovery;Environmental impact;Incineration;Landfilli	10.1016/j.energy.2023.127576

	te, J. and Żabnieńska-Góra, A. and Jouhara, H.		nt of plastic waste and energy recovery		entire life cycle of products, with legislation stating that plastic used throughout the design phase to manufacturing and packaging phases needs to be recyclable by 2030. This study evaluates selected plastic material categories and technologies carrying out a review of Life Cycle Assessment (LCA) analysis from literature. The literature review was carried out, the indicator units for impact categories among the investigated mid-point methodologies as well as the conversion factors for the metrics harmonization were provided and finally a detailed analysis of the environmental impact of several types of plastics was carried out for two options in the waste hierarchy, which are through disposal by sending waste to landfills and incineration with energy recovery. The disposal, treatment and recycling of 2.2 tonnes of general plastic waste including non-recyclable material delivered to a recycling facility was considered for comparison with these methods. An assessment of the comparative advantages of each practice was conducted. The potential for energy recovery was highlighted. © 2023 The Authors	ng;Plastic waste management;Elastomers;Life cycle;Plastic products;Plastic recycling;Product design;Waste disposal;Waste incineration;Waste treatment;Circular economy;Design phase;Energy recovery;Entire life cycles;Landfilling;Plastic energy;Plastic pollutions;Plastic waste management;Plastics waste;Waste recoveries;Environmental impact;energy resource;environmental impact;incineration;landfill;life cycle analysis;literature review;plastic waste;waste management	
69	Latif, A. and Cahyandito, M.F. and Utama, G.L.	2023	Circular Economy Concept at the Micro-Level: A Case Study of Taruna Mukti Farmer Group, Bandung Regency, West Java, Indonesia	Agriculture (Switzerland)	The concept of a circular economy can be utilized in the process of starting a dairy cattle enterprise. A circular economy is not only a chance to lessen the amount of waste produced by dairy farms and cut down on the amount of pollution that is released into the environment, but also an attempt to maximize the number of advantages that are shared between the economy and the environment. A circular economy can be implemented at any level, from the micro-level (businesses and customers) to the meso-level (eco-industrial zones), and all the way up to the macro-level (city, province, or country). The identification of circular economy practices is possible through the use of Circular Performance Indicators (CPIs). The purpose of this research is to identify circular economy practices based on CPIs at the micro-level, with a focus on the Taruna Mukti Farmer Group in the Bandung Regency of West Java, Indonesia. Based on our research, it is found that the identified CPIs achieve an average score of 2.57, with an achievement level value of 85.5% (very good). The results of the MICMAC analysis show that the key indicator in the CPIs of livestock waste management in the Taruna Mukti Farmer Group is additional income/income from the processing of livestock waste (C1). There is a relationship between the management of livestock waste in the Taruna Mukti Farmer Group and the circular economy concept based on Circular Performance Indicators. Farmers see the aspect of economic profit (economic motive) as important in the management of livestock waste. Marketing and sales strategies will have a big influence on the system of converting livestock waste into organic fertilizer. The higher the sales volume, the higher the level of profit. © 2023 by the authors.	circular economy;dairy farm;sustainability	10.3390/agriculture13030539
70	Escribà-Gelonch, M. and Butler, G.D. and Goswami, A. and Tran, N.N. and Hessel, V.	2023	Definition of agronomic circular economy metrics and use for assessment for a nanofertil	Plant Physiology and Biochemistry	Circular economy has become global priority, and fertigation make large contribution. Modern circular methodologies base their definitions, besides on waste minimisation and recovery, on the product usage U and lifetime L. We have modified a commonly used equation for the mass circularity indicator (MCI) to permit MCI determination for agricultural cultivation. We defined U as intensity for diverse investigated parameters of plant growth and L as the bioavailability period. In this way, we compute circularity metrics for the plantgrowth performance when exposed to three nanofertilizers and one biostimulant, as compared to no-use of micronutrients (control 1), and micronutrients supplied via conventional fertilizers (control 2). We determined an MCI of 0.839 for best nanofertilizer performance (1.000 denotes full circularity), while the MCI of	Biological cycles;Circular economy;Life cycle assessment;Nanofertilizers;Utility factor;copper;iron;manganese;trace element;agriculture;procedures;Agriculture;Copper;Iron;Manganese;Micronutrients	10.1016/j.plaphy.2023.02.042

			izer case study		conventional fertilizer was 0.364. Normalised to control 1, U was determined as 1.196, 1.121 and 1.149 for manganese, copper and iron-based nanofertilizers, respectively, while U was 1.709, 1.432, 1.424 and 1.259 for manganese, copper, iron nanofertilizers and gold biostimulant when normalised to control 2, respectively. Based on the learning of the plant growth experiments, a tailored process design is proposed for the use of nanoparticles with pre-conditioning, post-processing and recycling steps. A life cycle assessment shows that the additional use of pumps for this process design does not increase energy costs, while preserving environmental advantages related to the lower water usage of the nanofertilizers. Moreover, the impact of the losses of conventional fertilisers by missing absorption of plant roots, which is presumed to be lower for the nanofertilizers. © 2023		
71	Hitt, C. and Douglas, J. and Keoleian, G.	2023	Parametric life cycle assessment modeling of reusable and single-use restaurant food container systems	Resources, Conservation and Recycling	Single-use packaging generates millions of tonnes of plastic waste per year – a circular economy waste-reduction strategy is to implement reusable container systems for restaurant takeout. We developed a parametric life cycle assessment (LCA) and cost model and used scenario analysis to study customer behavior effects on greenhouse gas (GHG) emissions, primary energy, water use, and cost of a reusable container system in Ann Arbor, Michigan. Under our base case scenario, the primary reusable container has lower impacts across most metrics than comparable single use containers. Benefits are sensitive to excess customer transportation; if 5% of customers make trips solely to return used containers, the reusable system has higher life cycle GHG emissions and primary energy use than single-use. Additionally, if a large fraction (close to 100%) of customers practice excess at-home washing of containers, the life cycle primary energy impacts will be greater than those of most single-use containers. © 2022 Elsevier B.V.	Greenhouse gas emissions;Life cycle assessment;Life cycle costs;Plastic waste;Reusable packaging;Takeout food containers;Cost benefit analysis;Gas emissions;Greenhouse gases;Sales;Food containers;Greenhouse gas emissions;Life cycle assessment;Life cycle assessment model;Life cycle cost;Plastics waste;Reusable containers;Reusable packaging;Single use;Takeout food container;Life cycle;detergent;emission;energy use;greenhouse gas;life cycle analysis;modeling;packaging waste;plastic waste;Article;cost benefit analysis;energy consumption;evapotranspiration;fluid intake;food intake;food waste;greenhouse gas emission;life cycle;life cycle assessment;Michigan;municipal solid waste;nonhuman;productivity;restaurant;sensitivity analysis;solid waste management;takeaway (food);traffic and transport;walking;Ann Arbor;United States	10.1016/j.resconrec.2022.106862
72	Havrysh, V. and Kalinichenko, A. and	2023	Sunflower Residues-Based	Processes	Fossil fuel price increases, their uneven distribution, environmental issues from their incineration, and lack of guarantees of their energy security are the main drivers for the development of green energy. Agricultural waste is an abundant resource for energy bioprocessing, which improves the functioning of the circular	biorefinery;carbon dioxide emission;circular economy;indicator;power generation;Agricultural	10.3390/pr11020630

	Pysarenko, P. and Samojlik, M.		Biorefinery: Circular Economy Indicators		economy. In this study, the following were used as the main indicators: the share of renewable energy and the benefit from it, the coefficient of cyclical use of biomass, and the reduction in carbon dioxide emissions. The ways in which sunflower waste is applied for energy purposes are emphasized. The highest comprehensive ecological and economic effects are shown to be achieved in the production of biogas from sunflower residues with the incineration of this biogas in cogeneration plants. The residues from the biogas plant that are left after fermentation should be used as a biofertilizer. Such a cyclic system allows not only the full processing of all biomass waste that significantly reduces carbon dioxide emissions during the cultivation and processing of sunflower, but also an increase in the share of renewable energy used in technological processes up to 70%. © 2023 by the authors.	wastes;Carbon dioxide;Cogeneration plants;Crops;Cultivation;Energy security;Fossil fuels;Global warming;Refining;Waste incineration;Abundant resources;Biorefineries;Carbon dioxide emissions;Circular economy;Environmental issues;Fuel prices;Green energy;Power-generations;Price increase;Renewable energies;Biogas	
73	Gracida-Alvarez, U.R. and Xu, H. and Benavides, P.T. and Wang, M. and Hawkins, T.R.	2023	Circular Economy Sustainability Analysis Framework for Plastics: Application for Poly(ethylene Terephthalate) (PET)	ACS Sustainable Chemistry and Engineering	The establishment of the circular economy (CE) for plastics aims to reduce material losses and dependence on virgin materials; however, this practice does not necessarily imply reduction of life-cycle impacts. In this study, a CE sustainability analysis framework combining life-cycle assessment (LCA) and material flow analysis (MFA) was developed to simultaneously evaluate the life-cycle impacts and circularity metrics of implementing different CE strategies of production of plastic packaging, using poly(ethylene terephthalate) (PET) bottles as an example. The strategies included increasing the recycling rate of PET bottles and integrating two chemical recycling technologies in industrial development: enzymatic hydrolysis and methanolysis. The energy use of enzymatic hydrolysis and methanolysis was estimated to be 57 and 38 MJ/kg PET, respectively, while the two technologies accounted for greenhouse gas (GHG) emissions of 3.0 and 2.0 kg CO<inf>2</inf> e/kg PET, respectively. The analysis at the system level demonstrated that compared to the current practice, relying on 97% virgin PET resin, the joint implementation of these strategies generated similar GHG emissions (3.2 kg CO<inf>2</inf> e/kg bottle) but reduced virgin material use and solid waste generation by 56 and 64%, respectively. Based on present technology development, increasing the share of mechanically recycled resin in bottle manufacturing and using a decarbonized electricity grid resulted in 14 and 9% lower GHG emissions, respectively, than the current supply chain. © 2023 UChicago Argonne, LLC, Operator of Argonne National Laboratory. Published by American Chemical Society.	chemical recycling;circular economy;enzymatic hydrolysis;life-cycle assessment;material flow analysis;methanolysis;poly(ethylene terephthalate);upcycling;Carbon dioxide;Elastomers;Enzymatic hydrolysis;Ethylene;Fossil fuels;Gas emissions;Greenhouse gases;Life cycle;Plastic bottles;Plastic recycling;Resins;Sustainable development;Chemical recycling;Circular economy;Greenhouse gas emissions;Life-cycle assessment;Materials flow analysis;Methanolysis;Poly(ethylene terephthalate);Poly(ethylene) terephthalate;Sustainability analysis;Upcycling;Polyethylene terephthalates	10.1021/acssuschemeng.2c04626
74	Paoli, R. and Feofilovs, M. and Kamenders, A. and Romagnoli, F.	2022	Peat production for horticultural use in the Latvian context: sustainability assessment through	Journal of Cleaner Production	– Peat is used in various fields, from energy sources to fertilizer substrates. Peat bogs account for 3% of the earth's surface and represent a significant natural environment and carbon sink. Latvia is one of the European countries with the highest percentage of them and peat extraction plays an important role in the national economic market. Thus, the peat sector must be sustainably managed to regulate exploitation. In this context, this study's objective is to evaluate the overall environmental impact of the peat product chain. The tool used is a Life Cycle Assessment analysis (LCA), using a database made with primary data from a Latvian peat company and secondary data from a life cycle inventory database (Ecoinvent v3.7.1). The functional unit chosen is 1 m3 of peat substrate made for professional and non-professional horticultural use, a reference that consistently compares other standard substrates, namely coir pith and rock wool. The system boundaries include all the procedures from peat extraction to the product's end-of-	Circular economy;GHG emissions;Horticultural industry;LCA;Peat;Sustainability;Climate change;Environmental impact;Extraction;Greenhouse gases;Life cycle;Substrates;Sustainable development;Wool;Yarn;Circular economy;Coir pith;GHG emission;GHGs emissions;Horticultural industry;Life cycle	10.1016/j.jclepro.2022.134559

			LCA modeling		life. Results of the study expressed with an ecological score (i.e., Pt) show that the stage that produces the most significant impact is that of the distribution of the final product for Human health (2.3 mPt), Climate change (1.39 mPt), and Resources (1.48 mPt) indicators and it is related to use of the diesel fuel. While for the Ecosystem quality indicator is peat extraction (1.59 mPt) and it is connected to the peat bogs opening. From the comparison with other alternative substrates for horticultural use, it has been concluded that coir pith has the highest impact (48.51 mPt), followed by rock wool (10.6 mPt) and peat (6.79 mPt). © 2022 Elsevier Ltd	assessment analysis;Peat bogs;Peat production;Rock wool;Sustainability assessment;Peat	
75	Quirós, R. and Halog, A. and Muñoz, P.	2022	Environmental Assessment of Two Irrigation Systems in an Organic Tomato Crop System Under Manure Compost Fertilization: a Sustainable Circular Economy Approach in Catalonia (Spain)	Circular Economy and Sustainability	The circular economy is proposed as a promising strategy for both dealing with the current environmental issues and providing socio-economic benefits. The transformation of organic waste materials into a reusable product for crops is a way to contribute to the change from a linear economy to a circular model. Manure reuse as fertilizer is the most adequate option for the management of such material. This study aims to highlight the environmental impact assessment of two irrigation systems (i.e. integrated and dripping) of a tomato crop fertilized with manure compost and the integration of life assessment methodology with a circular economy. The life cycle assessment methodology was used to calculate the environmental impacts through the whole life cycle. Life cycle assessment is a methodology to assess the environmental performance of a product system in a circular approach. The research focused on the climate change impact category and the water applied to crops to know the effect on the yield of fruits. Overall, comparing two crop seasons, it was observed that a greater water supply contributed to higher yield fruit for the two irrigation systems studied. On the other hand, in regard to the environmental impacts, it was observed that the integrated system showed a better environmental performance than the dripping system for all categories assessed. Considering that livestock manure is transformed into organic fertilizer which is reintroduced into the agronomical system through the application to a tomato crop, a circularity indicator of 70% (organic fertilizer from the composting process × total mass of manure−1) was obtained in this agronomic system. © 2022, The Author(s), under exclusive licence to Springer Nature Switzerland AG.	Compost;Irrigation;Life cycle assessment;Manure;Tomato;Water	10.1007/s43615-022-00162-0
76	Wiedemann, S.G. and Nguyen, Q.V. and Clarke, S.J.	2022	Using LCA and Circularity Indicators to Measure the Sustainability of Textiles — Examples of Renewable and Non-Renewable Fibres	Sustainability (Switzerland)	Reducing environmental impacts by increasing circularity is highly relevant to the textiles sector. Here, we examine results from life cycle assessment (LCA) and circularity indicators applied to renewable and non-renewable fibres to evaluate the synergies between the two approaches for improving sustainability assessment of textiles. Using LCA, impacts were quantified for sweaters made from fossil feedstock-derived and bio-based PET. These same sweaters were scored using four circularity indicators. Both sweaters showed similar fossil energy footprints, but the bio-PET raw material acquisition stage greenhouse gas, water and land occupation impacts were 1.9 to 60 times higher, leading to higher full life cycle impacts. These contrasts were principally determined by what raw material acquisition processes were considered outside the system boundary of the alternative feedstocks. Using circularity indicators, fossil-feedstock PET scored lowest (worst) because the feedstock was from a non-renewable source. These examples highlight the limitations of LCA: the renewability or non-renewability of raw materials is not fully considered, and contrasts in processes included within system boundaries can preclude equitable comparisons. For LCA to be suitable for quantifying sustainability, it should be complemented by circularity indicators capable of demonstrating the contrast between renewable and non-renewable raw materials, particularly in the case of textiles. © 2022 by the authors.	apparel;bio-based;circular;fiber;footprint;PEF;synthetic;system boundary;textiles;environmental impact;life cycle analysis;nonrenewable resource;sustainability	10.3390/su142416683
77	Shou, M. and Doménech, T.	2022	Integrating LCA and blockchai	Journal of Cleaner Production	The textile sector accounts for the fourth-highest usage of primary raw materials and water (after food, housing, and transport), the second-highest usage of land, and the fifth highest Green House Gases (GHG) emissions (EEA, 2017). While Life Cycle Assessment (LCA) has been widely used to assess the environmental	Block chain;Circular economy;Circular fashion;Fashion;Life cycle assessment;Blockchain;Envir	10.1016/j.jclepro.2022.133557

			n technology to promote circular fashion – A case study of leather handbags		impact of fashion, most studies are constrained by the lack of reliable data. Blockchain technology may enable better traceability by making origin and journey more transparent. The potential to integrate LCA and blockchain has been discussed in other sectors, but specific protocols in the fashion sector are largely missing. This study aims to address this by a) exploring the use of LCA to measure the impact reduction potential of circular strategies and b) proposing a protocol for the integration of LCA and BC to accurately assess circular practices. Using leather handbags as a case study, an LCA study is conducted comparing two circular scenarios against a baseline to quantify potential benefits from circular strategies. Subsequently, it builds a blockchain-based LCA framework to unleash circularity opportunities through enhanced traceability and data sharing. Results point to substantial environmental benefits from the circular strategies, for example, circular scenario 2 (reuse markets/second-hand leather bag) was estimated to cause between 34.8% and 53.8% lower impacts while circular scenario 1 (leather alternative) contributed to impact reduction of more than 35% of the impacts in most impact categories (10 out of 18). The results also highlight the contribution of blockchain technology to enable traceability and reliable data for identification of environmental hotspots and accurate quantification of circular potential. © 2022 The Authors	onmental impact;Environmental technology;Greenhouse gases;Leather;Block-chain;Case-studies;Circular economy;Circular fashion;Circular strategies;Fashion;Greenhouse gas emissions;Impact reduction;Life cycle assessment;Textile sector;Life cycle	
78	Gallo, M. and Arrighi, G. and Moreschi, L. and Del Borghi, A. and Athanassiou, A. and Perotto, G.	2022	Life Cycle Assessment of a Circular Economy Process for Tray Production via Water-Based Upcycling of Vegetable Waste	ACS Sustainable Chemistry and Engineering	With one-third of food being wasted at the various steps of the value chain, there is a large amount of biomass constantly being discarded, also wasting the resources consumed for its production. Several strategies have been proposed to use this biomass as a source of raw materials for the production of plastic alternatives, but the environmental impact parameters have rarely been estimated to understand if the proposed process provides an overall benefit. The purpose of this paper is to analyze, through an experimental laboratory campaign, the production process of a vegetable biocomposite material obtained by valorization of biomass from two sources: unsold vegetables from a wholesale market and carrot pomace obtained as a byproduct of juicing. The obtained biocomposite films were thermoformed into trays to replace the traditional plastic food containers made principally with PET. Different scenarios for the lab-scale production of trays were evaluated by testing two water-based processing methods for the two types of biomass used. In order to understand which of the four scenarios was the least impactful, the global warming potential, the cumulative energy demand, and the water scarcity index were used as indicators. Among the different lab-scale processing scenarios for the upscaling of vegetable waste, the least impactful was starting from the unsold/discarded vegetables collected at the wholesale market that were processed via water-based hydrolysis catalyzed by formic acid. Impact parameters were comparable or better than two traditional polymers (PET and HDPE) and two biopolymers (PLA and biopolymer from starch), showing that this process has excellent potential, from an environmental point of view, of substituting plastic packaging. © 2022 American Chemical Society.	biocomposite materials;circular economy;food packaging;life cycle approach;water-energy-food nexus;Biomass;Biomolecules;Commerce;Environmental impact;Global warming;Life cycle;Packaging materials;Processing;Vegetables;Biocomposite materials;Circular economy;Food packaging;Impact-parameter;Life cycle approach;Vegetable wastes;Water based;Water energy;Water-energy-food nexus;Wholesale markets;Biopolymers	10.1021/acssuschemeng.2c02942
79	Vadoudi, K. and Deckers, P. and Demuytere, C. and Askanian, H. and Verney, V.	2022	Comparing a material circularity indicator to life cycle assessment: The case of a three-layer	Sustainable Production and Consumption	There is a serious need to assess the evolution of transitions from a linear to a Circular Economy (CE) using tools, metrics, and measurement indicators that not only are able to take into account the circularity, but also the other sustainability performances of products. Currently, most measurement tools do not lead to valuable decisions, as they do not capture the performance of the CE in its entirety, resulting in poorer performance on certain aspects, such as the environment. In addition, the lack of industry-specific indicators may hinder the adaptation of CE due to the different structures and functions of products. Consequently, this paper proposes a circularity indicator adapted from the Material Circularity Indicator (MCI) for the plastic industry, specifically Multi-layer Plastic Packaging (MPP). The adapted indicator is expanded based on the quality of recycled polymers by defining a new utility factor (X) as the polymers' intensity of re-use. It also highlights that it is necessary to combine a circularity indicator with Life Cycle	Circular economy;Circularity indicator;Closed-loop recycling;Life cycle assessment (LCA);Micro-scale;Multi-layer plastic packaging;Economic and social effects;Environmental impact;Eutrophication;Land use;Packaging;Plastic recycling;Sustainable development;Waste incineration;Circular economy;Circularity	10.1016/j.spc.2022.08.004

			plastic packaging		Assessment (LCA) for viable end-of-life (EOL) management. To illustrate the use of the proposed indicator and the trade-offs between circularity and environmental impacts, a case study on three-layer plastic packaging is applied to two end-of-life scenarios (Incineration, and closed-loop mechanical recycling). The results show that an increase in material circularity generally decreases the environmental impacts. However, recycling was found to have a higher impact than incineration on some impact categories such as land use and freshwater eutrophication. © 2022	indicator;Closed-loop;Closed-loop recycling;Life cycle assessment;Micro-scale;Multi-layer plastic packaging;Multi-layers;Plastic packaging;Three-layer;Life cycle	
80	Sazdovski, I. and Bojović, D. and Batlle-Bayer, L. and Aldaco, R. and Margallo, M. and Fullana–i–Palmer, P.	2022	Circular Economy of Packaging and Relativity of Time in Packaging Life Cycle	Resources, Conservation and Recycling	This paper introduces a new methodology for the analysis of the time of recycling to compare different life cycle assessments (LCA). We apply the three variables that define the value creation principles in the Ellen MacArthur Foundation's definition of circularity: material, energy and time. Including time in the LCA methodology improves understanding of the system under study, especially for products that have a relatively short usage time compared to their recycling time. We developed a formula that includes the time necessary for obtaining the secondary material needed for "n+1" product. The paper shows that we need to consider the production of additional packaging products, quantity of which depends on the time needed for recycling, to develop comparative LCAs between systems that serve same function. The proposed approach to packaging LCA contributes to the scientific debate over the allocation of credits and burdens between several consecutive life cycles of a material. © 2022	Circularity metrics;LCA;Life cycle;Time;Packaging;Recycling;Assessment methodologies;Circular economy;Circularity metric;Energy;Packaging products;Secondary materials;Time;Usage time;Value creation;Life cycle;life cycle analysis;packaging waste;recycling;sustainability;waste management;article;economic aspect;life cycle assessment	10.1016/j.resconrec.2022.106393
81	Golkaram, M. and Mehta, R. and Taveau, M. and Schwarz, A. and Gankema, H. and Urbanus, J.H. and de Simon, L. and Cakir-Benthem, S. and van Harmelen, T.	2022	Quality model for recycled plastics (QMRP): An indicator for holistic and consistent quality assessment of recycled plastics using product functionality and material properties	Journal of Cleaner Production	One of the key challenges for plastics in a circular economy is its degradation during use, washing and reprocessing. The reduced quality of recycled plastic waste leads to its use in inferior applications. This study presents a novel quality model which incorporates degradation, degree of mixing and contaminations. The model estimates a single quality value between 0 and 1 based on the mathematical relationship that uses: 1) a list of material properties, 2) minimum and maximum permissible values per property, 3) an ideal or desired value (or range) for the property and 4) relative importance (or weighing) factor (J) for the property. The quality model for recycled plastic (QMRP) was tested for three different real-life scenarios to evaluate the quality of recycled plastic for applications in food packaging film and toys. The results showed the superior prediction of QMRP in comparison to the existing models, in terms of application-based assessment, inclusion of all aspects of quality, credit allocation to upcycling and the use of a Go/No-go criteria. A single value quality indicator is to be applied in correlation studies, application prioritization for product development, managerial decision making and as a substitution ratio for the allocation of avoided products in life cycle assessment (LCA) studies. The QMRP indicator can be used by the recyclers to assess the quality of its material and strategically position their recycled plastic grades in the market. © 2022 Elsevier Ltd	Life cycle assessment;Material properties;Plastic;Quality model;Recycling;Decision making;Elastomers;Life cycle;Packaging materials;Plastic products;Plastics industry;Circular economy;Consistent quality;Degradation degree;Degree of mixing;Plastic;Plastics waste;Property;Quality assessment;Quality modeling;Recycled plastics;Plastic recycling	10.1016/j.jclepro.2022.132311
82	Cristiano, S. and Baarset, H. and Bruckner, C. and Johansen, J. and Pastres, R.	2022	Innovative options for the reuse and valorisation of aquaculture sludge	Journal of Cleaner Production	Two Life-Cycle Assessments (LCAs) were conducted to evaluate the environmental performances of selected novel eco-intensification innovations for the treatment and valorisation of sludge and fish mortalities from finfish aquaculture. The first innovation is based on a new process for filtering and drying particles from the reject water from a Recirculating Aquaculture System (RAS), with end-of-life recovery of nutrients and biomass to be reused as organic fertiliser or as energy source. The second process is based on a new device for drying fish mortalities and reusing the end-product as ingredient in the pet food industry or as	Circular economy;Environment;Farmed finfish;Health;Purification: filtration;Recirculating aquaculture system (RAS);Safety;Wastewater;Aquaculture;Drying;Environme	10.1016/j.jclepro.2022.131613

			and fish mortalities: Sustainability evaluation through Life-Cycle Assessment		energy source. Innovations refer to a functional unit of 1 ton of farmed fish and of fish mortalities, respectively, and were tested with a RAS for smolt production within the physical system boundary of a Norwegian facility. A set of standard indicators was selected for the Life-Cycle Impact Assessment (LCIA). The results indicate that the new processes compare well with the established ones, showing a marked decrease in most impact categories: indicators decrease by −12% through to −67% when sludge treatment innovations are applied, and by more than −86% after novel changes about fish mortality, with water consumption instead increasing by +7% and up to +50%, respectively. Furthermore, the analysis provided insights which could lead to improve their environmental performances. © 2022 The Authors	ntal management;Fertilizers;Filtration;Life cycle;Sustainable development;Circular economy;Energy source;Environment;Environmental performance;Farmed finfish;Purification: filtration;Recirculating aquaculture system;Reuse;Valorisation;Fish	
83	Scagnetti, C. and Lorenz, M. and Keller, J. and Albrecht, S.	2022	The Packaging Index (PIX) - a proposed methodology for packaging assessment and comparison	E3S Web of Conferences	The use of packaging and the related environmental consequences are increasingly under discussion. Despite its advantages, packaging has become the focus of public concern, mainly due to insufficient or inadequate handling of packaging waste. There is plenty of research regarding the sustainability of packaging options; however, multiple quantifiable characteristics have never been combined into a single indicator. The proposed Packaging Index (PIX) offers a tool to evaluate and compare different packaging options for the same product. To achieve these goals, the current evaluation criteria for the PIX are i) packaging quantity, ii) recyclability, and iii) environmental footprint. The resulting assessment is displayed as best to worst case scenario, with a single score for simple comparison. Using life cycle thinking, the environmental footprint of the packaging is accounted from cradle-to-grave. The suggested visualization of the PIX represents a practical comparison of diverse packaging alternatives within a defined product group. In the illustrative example, the PIX serves as an instrument to compare available bags found commonly in German online-retail. This example also shows that the PIX can analyze the packaging value chain from diverse industries and contributes to the circular economy. The usability of the PIX extends from communication (such as customer relations) to other fields like internal supply chain optimization. Lastly, we present the communication strategy of the PIX aimed at two different user groups. © The Authors, published by EDP Sciences.		10.1051/e3sconf/202234901002
84	Silva, C. and Moniz, P. and Oliveira, A.C. and Vercelli, S. and Reis, A. and Lopes da Silva, T.L.	2022	Cascading Crypthecodinium cohnii Biorefinery: Global Warming Potential and Techno-Economic Assessment	Energies	Prior to the commissioning of a new industrial biorefinery it is deemed necessary to evaluate if the new project will be beneficial or detrimental to climate change, one of the main drivers for the sustainable development goals (SDG) of the United Nations. In particular, how SDG 7, Clean and Efficient Energy, SDG 3, Good Health and Well Being, SDG 9, Industry Innovation and Infrastructure, and SDG 12, Responsible Production and Consumption, would engage in a new biorefinery design, beneficial to climate change, i.e., fostering SDG 13, Climate Action. This study uses life cycle assessment methodology (LCA) to delve in detail into the Global Warming Impact category, project scenario GHG savings, using a conventional and a dynamic emission flux approach until 2060 (30-year lifetime). Water, heat and electricity circularity are in place by using a water recirculation process and a combined heat and power unit (CHP). A new historical approach to derive low and higher-end commodity prices (chemicals, electricity, heat, jet/maritime fuel, DHA, N-fertilizer) is used for the calculation of the economic indicators: Return of investment (ROI) and inflation-adjusted return (IAR), based upon the consumer price index (CPI). Main conclusions are: supercritical fluid extraction is the hotspot of energy consumption; C. cohnii bio-oil without DHA has higher sulfur concentration than crude oil based jet fuel requiring desulfurization, however the sulfur levels are compatible with maritime fuels; starting its operation in 2030, by 2100 an overall GHG savings of 73% (conventional LCA approach) or 85% (dynamic LCA approach) is projected; economic feasibility for oil productivity and content of 0.14 g/L/h and 27% (w/w)	advanced fuel;conventional and dynamic LCA;DHA nutritional supplement;district heating;N-Fertilizer;net zero carbon electricity 2050;water and energy circularity;Bioconversion;Carbon;Cost engineering;Costs;Economics;Effluent treatment;Energy utilization;Environmental impact;Fertilizers;Genetic engineering;Global warming;Greenhouse gases;Life cycle;Refining;Sulfur;Supercritical fluids;Advanced fuels;Assessment methodologies;Conventional and dynamic life cycle assessment	10.3390/en15103784

					oil content, respectively (of which 31% is DHA), occurs for DHA-cost 100 times higher than reference fish oil based DHA; however future genetic engineering achieving 0.4 g/L/h and 70% (w/w) oil content (of which 31% is DHA), reduces the threshold to 20 times higher cost than reference fish oil based DHA; N-fertilizer, district heating and jet fuel may have similar values then their fossil counterparts. © 2022 by the authors. Licensee MDPI, Basel, Switzerland.	methodology;DHA nutritional supplement;N fertilizers;Net zero carbon electricity 2050;Nutritional supplements;Water and energies;Water and energy circularity;Zero carbons;Investments	
85	Salah, F. and Vololonirina, O. and Gidik, H.	2022	Development of fibrous materials applied in timber-framed construction using recycled fibers from textile waste	Journal of Cleaner Production	The paper deals with the reuse of fibers from textile waste for the development of innovative and sustainable materials applied in the construction field. Currently, managing the high volumes of textile waste produced, and reducing the damage this waste does to the ecosystem, involves finding solutions for its reuse. Meanwhile, the construction sector has a great impact on the environment, and there is an urgent need to design innovative, sustainable building materials to reduce energy consumption and prevent the depletion of resources. In this context, the objective of the MOBIOTEX project is to develop new materials to replace the petrochemical-made vapor-barrier (VB) and rain-screen (RS) generally used in timber-frame construction (TFC). For that, nonwoven (NW) fabrics from textile waste were manufactured. Then, measurements based on standards for VB and RS were carried out on untreated and functionalized NW fabrics, to test their sealing and mechanical properties. Lamination of NW gives satisfactory results and some modified materials meet the requirements for both VB and RS applications and have similar properties as commercial products. These first results are quite promising as they show that, with some treatment, nonwoven from textile waste can be as technically efficient as commercial products. The different processes used during the MOBIOTEX project made it possible to build up the system boundary for the production of functionalized nonwoven in order to carry out future Life Cycle Assessment (LCA) and to compare with commercial products' LCA. In a circular economy approach, other characteristics such as durability, fire resistance and recyclability of such materials should be studied and optimized in order to reduce energy consumption and environmental impacts. Still, the main benefit of the developed materials, compared to commercial petrochemical rain-screens and vapor barriers, is on the production of raw materials, because it involves less exploitation of non-renewable resources, as an important part of materials come from waste, and the application in timber-framed construction can be a positive way in which to reuse a non-negligible volume of waste from the textile industry. © 2022 Elsevier Ltd	Nonwoven;Rain-screen;Recycled fibers;Textile waste;Timber-frame construction;Vapor barrier;Building materials;Energy utilization;Environmental impact;Intelligent buildings;Life cycle;Nonwoven fabrics;Rain;Sustainable development;Timber;Waste treatment;Commercial products;Fibrous material;Functionalized;Non-woven;Rain-screen;Recycled fibers;Reduce energy consumption;Reuse;Timber frame construction;Vapor barriers;Construction industry	10.1016/j.jclepro.2022.131203
86	Keller, J. and Scagnetti, C. and Albrecht, S.	2022	The Relevance of Recyclability for the Life Cycle Assessment of Packaging Based on Design for Life Cycle	Sustainability (Switzerland)	The awareness for more environmentally sustainable packaging solutions is steadily grow-ing. With both consumers and manufacturers looking to minimize their impacts on the environment, the need for easy-to-implement and standardized measures strengthening a circular economy rises. In the research, the goal was to determine whether the carbon footprint and circularity of non-food plastic packaging can be improved by simple design changes. The results should then lead to design recommendations, providing a Design for Life Cycle approach. The methodology of the study was to conceptually design a single-use plastic packaging with attributes having positive and negative effects on recyclability. Herein, only design characteristics from products obtainable on the market were regarded. Moreover, a comparison over existing recyclability assessment methods is given. The recyclability was then determined with the selected approach by Cyclos HTP, and a reference calculation was conducted. Life Cycle Assessments were implemented for 14 packaging designs using the GaBi software and the Environmental Footprint method. The results showed that dark color, material compounds, insoluble adhesives, and large labels result in lower recyclability of the single-use packaging. The impacts on climate change range from 0.13 kg CO<inf>2</inf>-equivalent emissions (100% recyclability) to 0.21 kg	circular design;circular economy;climate change;Design for Life Cycle;life cycle assessment;plastic packaging;producer responsibility;recyclability;waste management;carbon footprint;design method;environmental assessment;life cycle analysis;waste management	10.3390/su14074076

					CO<inf>2</inf>-equivalent emissions (0% recyclability) per packaging, showing that lower recyclability leads to a larger carbon footprint in all assessed scenarios. Concluding, the research demonstrated that by applying Design for Life Cycle measures, impacts on climate change can be reduced. Lastly, design recommendations for decision makers are outlined. © 2022 by the authors. Licensee MDPI, Basel, Switzerland.		
87	Preisner, M. and Smol, M. and Horttanainen, M. and Deviatkin, I. and Havukainen, J. and Kļaviņš, M. and Ozola-Davidāne, R. and Kruopienė, J. and Szatkowska, B. and Appels, L. and Houtmeyers, S. and Roosalu, K.	2022	Indicators for resource recovery monitoring within the circular economy model implementation in the wastewater sector	Journal of Environmental Management	The European Union is currently in the process of transformation toward a circular economy model in which different areas of activity should be integrated for more efficient management of raw materials and waste. The wastewater sector has a great potential in this regard and therefore is an important element of the transformation process to the circular economy model. The targets of the circular economy policy framework such as resource recovery are tightly connected with the wastewater treatment processes and sewage sludge management. With this in view, the present study aims to review existing indicators on resource recovery that can enable efficient monitoring of the sustainable and circular solutions implemented in the wastewater sector. Within the reviewed indicators, most of them were focused on technological aspects of resource recovery processes such as nutrient removal efficiency, sewage sludge processing methods and environmental aspects as the pollutant share in the sewage sludge or its ashes. Moreover, other wide-scope indicators such as the wastewater service coverage or the production of bio-based fertilizers and hydrochar within the wastewater sector were analyzed. The results were used for the development of recommendations for improving the resources recovery monitoring framework in the wastewater sector and a proposal of a circularity indicator for a wastewater treatment plant highlighting new challenges for further researches and wastewater professionals. © 2021 Elsevier Ltd	Circular economy;Fertilizers;Indicators;Nutrients;Phosphorus;Resource recovery;Sewage sludge;Wastewater sector;Wastewater treatment;Fertilizers;Nutrients;Phosphorus;Reclamation;Wastewater treatment;Area of activities;Circular economy;Efficient managements;European union;Model implementation;Policy framework;Resource recovery;Transformation process;Wastewater sector;Wastewater treatment process;Sewage sludge;biogas;fertilizer;nitrogen;organic matter;phosphorus;economic policy;environmental economics;European Union;resource use;sustainability;sustainable development;waste management;wastewater;wastewater treatment;wastewater treatment plant;water industry;bioavailability;carbonization;chemical oxygen demand;composting;economic aspect;effluent;energy recovery;environmental indicator;inorganic nutrient;nutrient content;performance indicator;recycling;Review;sewage;waste component removal;waste water recycling;waste water treatment plant;water monitoring;water management;Sewage;Waste Disposal, Fluid;Waste Water;Water Purification	10.1016/j.jenvman.2021.114261
88	Betts, K. and	2022	Key metrics	Frontiers in Sustainability	Circular supply chains comprise the industrial production and supply chain systems used by companies to eliminate waste and recover value in products and	circular supply chain (CSC);performance indicator	10.3389/frsus.2022.910215

	Gutierrez-Franco, E. and Ponce-Cueto, E.		to measure the performance and impact of reusable packaging in circular supply chains		materials. There are a variety of circular strategies including recycling in waste management, returns and repair in consumer-facing industries, and reusable packaging in supply chains. Successful implementation and management of these circular strategies requires the ability to measure and report on progress across different functions and processes. In this paper, we propose a new set of metrics to measure the performance of reusing items in a circular supply chain. We review the literature on metrics in circular supply chain management and reusable packaging in supply chains. We then classify the proposed metrics based on whether they measure the circularity of a circular supply chain initiative or impact of implementing the initiative. They also are segmented based on the level of detail they incorporate from the product level to the system level. We then demonstrate the use of the proposed metrics through a case study with an omnichannel retail company. We find that product-level metrics facilitate the comparison of different types of reusable and single-use packages with the potential to reduce lifecycle greenhouse gas emissions. We also find that measuring system-level Total Logistics Costs helps identify potential challenges with the feasibility of a reusable packaging system including the implications of not recovering packages and amortizing initial costs across multiple use cycles. Our aim in this paper is to address the gap in circularity and impact metrics focused on reuse strategies in supply chains. This new set of metrics provides companies with a tool to measure and report on progress toward a circular economy. It also suggests future avenues for research to assess the economic, environmental, and social dimensions of sustainability. © © 2022 Betts, Gutierrez-Franco and Ponce-Cueto.	(PI);retailer;reusable packaging;sustainability	
89	Roos Lindgreen, E. and Mondello, G. and Salomone, R. and Lanuzza, F. and Saija, G.	2021	Exploring the effectiveness of grey literature indicators and life cycle assessment in assessing circular economy at the micro level: a comparative analysis	International Journal of Life Cycle Assessment	Purpose: Methods and tools to measure Circular Economy (CE) are in an early stage of development, especially on the micro level, and only limited guidance is available to companies' decision-making processes related to CE solutions. In this context, the aim of this paper is to explore the suitability and effectiveness of grey literature CE indicators and the Life Cycle Assessment (LCA) method in measuring circularity at product or process level. Methods: The analysis is based on two different comparative case-studies specifically related to the packaging sector, including glass and polyethylene terephthalate (PET) bottles, and to the food waste (FW) management sector, focusing on specific FW treatment activities. A review-of-reviews of CE metrics at the micro level is presented first in order to provide a theoretical overview on this specific theme and identify the available grey literature CE indicators and the role of LCA. Then, inventory data from both case studies are used as input to calculate LCA indicators as well as selected product-level grey literature CE indicators. Finally, the results are compared to critically analyze the potentiality in assessing circularity of these two streams of CE micro level assessment (LCA and CE indicators). Results and discussion: The main findings underscore that despite the common purpose of the selected CE indicators, the results related to the circularity performance may strongly vary depending on the evaluated case study and on the type of grey literature CE indicator that is applied. Regarding the application of the LCA method, the results highlight that, although a product may present high circularity performance, it does not necessarily carry lower environmental burdens. In addition, the LCA method allows obtaining useful information about both the environmental and circularity performance of the assessed case-studies. Conclusions: The LCA method is presented as a suitable and effective method that businesses can apply to start a commitment towards CE. LCA can be considered the basic structured system on which to build a more complete metric framework for quantification of CE, specifically for companies that are aiming to operate more sustainably. On the contrary, grey literature CE indicators may not be always appropriate for assessing specific sectors or effectively contribute to assess environmental sustainability. © 2021, The Author(s), under exclusive licence to Springer-Verlag GmbH Germany, part of Springer Nature.	CE;Circular Economy assessment;Circular perspective;Food waste;LCA;Metrics;Micro level;Packaging;glass;polyethylene terephthalate;polyvinylchloride;Article;circular economy;commercial phenomena;comparative study;economic aspect;environmental factor;environmental sustainability;food waste;grey literature;life cycle assessment;packaging;qualitative analysis;quantitative analysis;systematic review;waste management	10.1007/s11367-021-01972-4

90	Tashkeel, R. and Rajarathnam, G.P. and Wan, W. and Soltani, B. and Abbas, A.	2021	Cost-normalized circular economy indicator and its application to post-consumer plastic packaging waste	Polymers	This work presents an adaptation of the material circularity indicator (MCI) that incorpo-rates economic consideration. The Ellen MacArthur Foundation (EMF) has developed the MCI to characterize the sustainability, viz., the “circularity”, of a product by utilizing life cycle assessment data of a product range rather than a single product unit. Our new “circo-economic” indicator (MCIE), combines product MCI in relation to total product mass, with a cost-normalization against estimated plastic recycling costs, for both separately collected and municipal solid waste. This is applied to assess Dutch post-consumer plastic packaging waste comprising polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), film, and mixed plastic products. Results show that MCIE of separate plastic collection (0.81) exceeds municipal solid waste (0.73) for most plastics, thus suggesting that under cost normalization, there is greater conformity of separately collected washed and milled goods to the circular economy. Cost sensitivity analyses show that improvements in plastic sorting technology and policy incentives that enable the production of MSW washed and milled goods at levels comparable to their separately collected counterparts may significantly improve their MCI. We highlight data policy changes and industry collaboration as key to enhanced circularity—emphasized by the restrictive nature of current Dutch policy regarding the release of plastic production, recycling, and costing data, with a general industry reluctance against market integration of weight-benchmarked recycled plastics. © 2021 by the authors. Licensee MDPI, Basel, Switzerland.	Circo-economics;Circular economy;Material circularity indicator;Packaging;Plastic waste;Cost benefit analysis;Costs;Elastomers;Life cycle;Municipal solid waste;Packaging;Plastic bottles;Polyethylene terephthalates;Polypropylenes;Sensitivity analysis;Circo-economic;Circular economy;Economic considerations;ITS applications;Material circularity indicator;Normalisation;Packaging waste;Plastic packaging;Plastics waste;Post-consumer;Plastic recycling	10.3390/polym13203456
91	Nimmegeers, P. and Billen, P.	2021	Quantifying the Separation Complexity of Mixed Plastic Waste Streams with Statistical Entropy: A Plastic Packaging Waste Case Study in Belgium	ACS Sustainable Chemistry and Engineering	Mixed plastic waste streams are to date present in nearly all societies. Depending on the source of the plastic waste stream, the complexity and difficulty to separate and recycle the waste stream differs. In this paper, the concept of statistical entropy is used to quantify the separation complexity of mixed plastic waste streams. To this end, the recently proposed multilevel statistical entropy analysis method is extended by adding a multiproduct system level. Furthermore, an overview is presented of the research questions that can be addressed by different statistical entropy definitions. The proposed extended method is applied to a plastic packaging waste case study in Belgium for which the data are available in the literature. The results indicate that the method based on statistical entropy allows analyzing the separation complexity of real-life mixed plastic waste streams. More specifically, the multilayer films contribute the most to the separation complexity of the studied plastic packaging waste stream. In addition, it is illustrated how the method can be used to identify key contributors to the separation complexity of mixed plastic waste streams and to evaluate measures to reduce the separation complexity of mixed plastic waste streams. © 2021 American Chemical Society	circular economy;plastic waste;recycling;resource efficiency;statistical entropy analysis;waste management;Entropy;Multilayer films;Statistics;Belgium;Multi-product systems;Plastic packaging;Plastic wastes;Research questions;Statistical entropy;Waste stream;Separation	10.1021/acssuschemeng.1c02404
92	Siddiqui, Z. and Hagare, D. and Jayasena, V. and Swick, R. and Rahman, M.M. and Boyle, N. and Ghodrat, M.	2021	Recycling of food waste to produce chicken feed and liquid fertiliser	Waste Management	Most of the food waste (FW) generated by commercial activities and the majority of household FW is collected as part of general waste, which is either incinerated or landfilled. There is an increasing interest in the collection of FW as a separate waste stream and use it for the production of compost or recovery of energy through anaerobic digestion (AD) or pyrolysis. This study focused on using FW to produce chicken feed and liquid fertiliser (CFLF). The food waste samples were collected from food related businesses such as service club, café, restaurant, bakery and supermarket. The CFLF process was used to produce chicken feed pellets containing 19% of protein content, which is within the range of 16 to 22% of most commercial chicken feed pellets and within the National Research Council (NRC) recommended range of 15 to 23%. The liquid extract derived from CFLF process had high nutrient concentrations similar to those present in the feed solution used in hydroponic systems. Hence, the liquid extract from CFLF can be used to replace the commercial liquid fertiliser used in hydroponic systems. Environmental impact analysis of CFLF process using GaBi life cycle analysis	Chicken feed;Circular economy;Food related business;Food waste;Hydroponic;Liquid fertiliser;Anaerobic digestion;Animals;Binary alloys;Composting;Food waste;Gallium alloys;Life cycle;Liquids;Pelletizing;Waste incineration;Anaerobics;Chicken feed;Circular economy;Environmental credits;Food related business;Household	10.1016/j.wasman.2021.06.016

					(LCA) software indicated that the CFLF process can yield environmental credits for 15 out of 19 categories of impacts considered in the analysis. The measured environmental credits were significantly higher than the other disposal options such as, anaerobic digestion (AD), incineration and landfill. © 2021	food;Hydroponic;Hydroponic systems;Liquid fertilizers;Fertilizers;fertilizer ;environmental impact assessment;food waste;hydroponics;life cycle analysis;protein;recycling;an aerobic digestion;animal food;Article;biomass;chicken ;economic aspect;environmental impact;food intake;greenhouse effect;incineration;landfill;lif e cycle;municipal solid waste;nutrient concentration;pyrolysis;anim al;food;waste disposal;waste management;Gallus gallus;Chickens;Food;Refuse Disposal;Waste Management	
93	Santos, Rute and Abreu, Maria Jose	2025	Impact Assessme nt and Product Life Cycle Analysis of Different Jersey Fabrics Using Conventi onal, Post-Industrial , and Post-Consume r Recycled Cotton Fibers	SUSTAINABILI TY			10.3390/su17135700
94	Sazdovski, I. and Bala, A. and Fullana–i–Palmer, P.	2021	Linking LCA literature with circular economy value creation: A review on beverage	Science of the Total Environment	The ever-increasing volume of packaging waste is widely recognised as a key global environmental challenge. Packaging is thus a central concern for advocates and analysts of circular economy (CEc), who often apply the life cycle assessment (LCA) methodology when measuring the environmental impacts of products and packaging. We undertook a systematic literature review as a research method, and in-depth analysis to ascertain the extent to which the new CEc paradigm has been integrated in LCA methodology applied to beverage packaging and reported in scientific papers. Carefully developed search strings returned 866 articles relevant to our enquiry from the databases of SCOPUS and Web of Science. Applying our selected eligibility criteria, we extracted a subset of 51 articles for in-depth analysis. The analysed literature shows the links between the quality of packaging	Beverage packaging;Circular economy;End-of-life;Life cycle assessment;Material quality;Recyclability;Bevera ges;Environmental impact;Life cycle;Packaging;Recycling;B reak-even analysis;Comparative assessment;Eligibility criterion;Environmental	10.1016/j.scitotenv.2021.1 45322

			packaging		material for recycling and the profoundness of the LCA studies. The paper provides the following set of recommendations for enhancing the future practice in development of the scientific LCAs for beverage packaging: (i) taking all direct and indirect factors into account when assessing the refillable beverage packaging system and conducting break-even analysis in order to achieve impartial comparative assessments of single-use and refillable systems; (ii) developing proxies in cases when actual data is lacking with which to model the recycling scenarios for exported secondary materials and hence improving the accuracy of recycling rate assessments in LCA models; (iii) improving the definition of the LCA function by introducing multiple loops of the packaging material and assessing qualitative changes in the material resulting from the multiple-recycling process. Thus improved practice of LCAs could better inform and improve the design of new packaging strategies aimed at prolonging the life of packaging materials in the technosphere, equally fulfilling the principles of the CEc. © 2021 Elsevier B.V.	challenges;Life Cycle Assessment (LCA);Qualitative changes;Secondary materials;Systematic literature review;Packaging materials;aluminum;glass;plastic;polyethylene terephthalate;beverage;environmental economics;life cycle analysis;literature review;material flow analysis;qualitative analysis;recycling;circular economy;data analysis;data base;data extraction;economic aspect;environmental aspects and related phenomena;environmental impact;food packaging;geographic distribution;life cycle assessment;plastic waste;product design;product quality;qualitative research;Review;waste management	
95	Dos Santos Gonçalves, P.V. and Barbosa, R.F.M. and Raspini, V.A.P. and Sehnem, S. and Campos, L.M.S.	2021	The use of circular economy indicators to improve sustainability in the recycling aluminium context		The Circular Economy is an important alternative to capture environmental profit from polluters and increase the competitiveness of productive sectors. This study aims to analyse how the Circular Economy (CE) indicators can contribute to improving the sustainability of recycling aluminium beverage packages in the Brazilian scenario. A literature review was conducted about CE indicators in aluminium-recycling context and a set of CE indicators were found and criticized in the context of sustainability. According to results, beverage packages have alternatives to be more circular, with correct ways to measure improvements and develop the sector, decreasing environmental threats and increasing recycling content. This study provided information to the metal industry, metal users, and the recycling industry of aluminium beverage packaging in Brazil. © IEOM Society International.		
96	Šuškevičė, V. and Kruopienė, J.	2021	Improvement of packaging circularity through the application of reusable beverage cup reuse models at	Sustainability (Switzerland)	Festivals generate huge amounts of waste during a short period of time, usually in three to four days. Single-use packaging is one of the dominant waste streams at the festivals. In order to minimize single-use plastic packaging waste generation and negative impacts on the environment, outdoor festivals apply alternative reusable cup systems and strategies. However, little studies have been made on how different reusable beverage cup reuse models can affect material circularity within certain festivals, and how it contributes to cup damage and loss. This article presents the results of a pilot study of different reusable cup reuse models within seven Lithuanian summer outdoor festivals. Three different models were applied and tested: A—only reusable cups, non-refundable model; B—only reusable cups, with deposit-refund; C—a mixed system of reusable cups with deposit-refund and of single-use cups. Material flow analysis (MFA) was performed, and the Materials Circularity Indicator (MCI), developed by Ellen MacArthur Foundation,	Circular economy;Circularity indicators;Deposit-refund system;Material flow analysis (MFA);Packaging waste;Resource efficiency;Reusable cups;Reuse systems;Sustainable events;Waste prevention;decision making;model;packaging waste;recycling;strategic approach;Indicator indicator	10.3390/su13010247

			outdoor festivals and events		was calculated to study the applied models. According to the findings, refund models (B, C models) have lower rates of damaged and lost cups compared to non-refundable reusable cup reuse model (A model). This paper shows that different reuse models provide different damage, loss and return rates of reusable cups. The data presented can aid decision-makers who need to choose a reuse model for a certain event. © 2020 by the authors. Licensee MDPI, Basel, Switzerland.		
97	Spagnolo, S. and Chinellato, G. and Cristiano, S. and Zucaro, A. and Gonella, F.	2020	Sustainability assessment of bioenergy at different scales: An emergy analysis of biogas power production	Journal of Cleaner Production	The purpose of this work is to present the application of Emergy Analysis to a biogas power plant, with the aim at assessing its integrated sustainability and studying how the emergy indicators of sustainability depend on the boundary selection. The object of the analysis is a biogas power plant fed on agriculture and zootechnical biomass. The complex interaction of the involved subsystems and the exchange of resource flows require powerful integrated analyses as well as the definition of reliable performance indicators. Emergy Analysis has been addressed as specifically useful to integrate the upstream and the downstream aspects along with the potential circularity of resource flows, providing in this way a quantitative estimation of the sustainability performance of the systems. The analysis was applied at two scales: the Reference System (biogas power plant plus the agricultural cultivations) and the Expanded System, which includes also the cattle breeding, whose main purpose is meat and milk production, but which provides the liquid cattle manure for the Reference System operation. The main emergy indicators have been calculated and reported: for the Reference System, the transformity of produced electricity results similar to fossil-based energy production systems; the Emergy Yield Ratio is about 1, showing that the system cannot be considered as an energy source, rather acting like a consumer; the Environmental Loading Ratio is very high, as the local renewable fraction of the resources exploited is very low compared to the non-renewable ones. The expansion of the system analysis allows to study the added value of linking the subsystems agriculture-breeding-energy production, which provide more products and services to the economy than the sole energy. The need of performing sustainability assessment at different scales appears to be presently the main issue in the analyses that should result suitable for the policy-making processes. © 2020 Elsevier Ltd	Agriculture;Biogas;Circular economy;Emergy;Renewable energy;Sustainability assessment;Agricultural robots;Biogas;Biomass;Cultivation;Economics;Electric power generation;Fertilizers;Manures;Power plants;Agricultural cultivation;Energy production systems;Environmental Loading Ratio;Products and services;Quantitative estimation;Reliable performance;Sustainability assessment;Sustainability performance;Sustainable development	10.1016/j.jclepro.2020.124038
98	Kakadellis, S. and Harris, Z.M.	2020	Don't scrap the waste: The need for broader system boundaries in bioplastic food packaging life-cycle assessment – A critical review	Journal of Cleaner Production	The increasing amount of plastic waste generated each year, fuelled by the growing consumption of single-use plastics in food packaging applications, threatens the integrity of our ecosystems while creating an unprecedented waste management crisis. The biodegradable properties of some bioplastics have been identified as a promising solution to divert food and food packaging waste from landfill while avoiding plastic leaking into the environment. However, such bio-based biodegradable alternatives may not necessarily provide an improvement in overall environmental impact, especially when considering their efficacy at preventing food waste. This is the first systematic review to investigate the relationship between food packaging and food waste, based on conventional and biodegradable plastic food packaging life-cycle assessments (LCAs). It focuses on the trade-offs that may occur between food packaging production, end-of-life management and food waste prevention across the entire food packaging life-cycle. Following a review of 111 papers, 19 were identified for further investigation and data extraction. Quantitative analysis for five LCA impact categories, as well as hotspot analysis and end-of-life scenario analysis for global warming potential were conducted. The resulting picture is conflicting and suggests that though bioplastics display environmental benefits for global warming potential and non-renewable energy use, these are often negated by the agricultural inputs required for bioplastics raw material production. While the LCAs included in this study do not provide enough evidence to state which polymer is best at reducing food waste, they emphasise the environmental footprint associated with food production and food waste, and highlight the importance of including the	Bioplastic;Food waste;Life-cycle assessment;Plastic packaging;Systematic literature review;Waste management;Agricultural robots;Anaerobic digestion;Biodegradable polymers;Conservation;Economic and social effects;Energy utilization;Food waste;Global warming;Landfill;Packaging;Packaging machines;Packaging materials;Plastic recycling;Plastics applications;Reinforced plastics;Scrap metal reprocessing;Waste incineration;Biodegradable plastics;Biophysical properties;End of life managements;Environmental	10.1016/j.jclepro.2020.122831

					food itself in food packaging LCAs. Therefore, focusing on food packaging performance in food waste minimisation is critical. We found that bioplastics provide the benefit of diverting biodegradable waste from landfill or incineration to 'greener' streams such as anaerobic digestion and composting, contributing to a circular economy. Encouraging biodegradable bioplastics should target plastic packaging where effective recycling measures are failing due to the challenges that remain for treating and recycling materials made of multiple, highly food-contaminated layers. The bioplastic industry is still young and optimising both the manufacturing process and material biophysical properties would contribute towards improving the overall environmental profiles of bioplastics. © 2020 The Author(s)	footprints;Global warming potential;Life Cycle Assessment (LCA);Non-renewable energy use;Raw material production;Life cycle	
99	Subramania n, K. and Chopra, S.S. and Cakin, E. and Li, X. and Lin, C.S.K.	2020	Environ mental life cycle assessme nt of textile bio-recycling – valorizin g cotton-polyester textile waste to pet fiber and glucose syrup	Resources, Conservation and Recycling	Emerging textile bio-recycling approaches can address the environmental challenges associated with the end-of-life of clothing. However, it is imperative to assess the environmental impacts associated with these technologies, systematically, to ensure they are environmentally sustainable. The objective of this study is to evaluate the environmental implications of a novel bio-recycling method that recovers polyester (PET) fibres and glucose, from 50/50 cotton/PET blend of fabric waste from H&M, using Life Cycle Assessment (LCA). The chosen functional unit is one kg of recovered PET fibre. Life Cycle Impact Assessment (LCIA) was conducted in terms of ReCiPe, both midpoint and endpoint indicators, and Cumulative Energy Demand (CED) impact categories. LCA results of the gate-to-cradle analysis indicate pre-treatment as the most dominant process, followed by melt-spinning and then enzymatic hydrolysis. Sensitivity analysis with Global Warming Potential (GWP) indicator shows that pre-treatment step influences the results and contributes to uncertainty. Pre-treatment (207 MJ) is also the most energy-intensive step, followed by melt-spinning (98.5 MJ) and enzymatic hydrolysis (44.8 MJ). We also describe linkages between addition of PET bottles in the melt-spinning step and environmental impacts. Environmental impacts on all three endpoints increased as the percentage of waste PET bottle chips added was decreased. LCA of the textile bio-recycling method suggests that environmental impacts can be further reduced, provided the involved unit processes are made more energy-efficient, and the fibre quality of the recovered polyester is improved such that it can be directly used for garment production without the need to add waste PET bottle chips. © 2020 Elsevier B.V.	Biological method;Circular economy;Enzymatic hydrolysis;Life cycle assessment;PET fibre;Textile recycling;Bottles;Cotton;Energy efficiency;Environmental technology;Enzymatic hydrolysis;Fibers;Garment industry;Global warming;Glucose;Life cycle;Melt spinning;Plastic recycling;Polyesters;Sensitivity analysis;Spinning (fibers);Textiles;Uncertainty analysis;Cumulative energy demands;Environmental challenges;Environmental implications;Environmental life cycle assessment;Global warming potential;Life cycle impact assessment;Polyester textiles;Recycling methods;Environmental impact;glucose;polyester;cotton;life cycle analysis;polymer;recycling;textile industry;waste management;Article;chemical procedures;controlled study;Cumulative Energy Demand;environmental aspects and related phenomena;environmental impact;environmental impact assessment;enzymatic hydrolysis;Global Warming Potential;industrial waste;life cycle assessment;melt spinning;pollution and pollution related phenomena;sensitivity analysis;syrup;Gossypium hirsutum	10.1016/j.resconrec.2020.104989

100	Reinales, D. and Zambrana-Vasquez, D. and Sáez de Guinoa, A.	2020	Social life cycle assessment of product value chains under a circular economy approach: A case study in the plastic packaging sector	Sustainability (Switzerland)	Environmental and economic impact assessment of products have a long record, while social performance analysis of products have less references in the scientific literature due its particularities and the adaptations needed for the features of the studied subject. In addition, there is a lack of a methodological framework of its application in the analysis of value chains, with the aim of estimating the impacts of technical innovations from the social point of view. This paper describes the theoretical framework and impact assessment approach for the Social Life Cycle Assessment of product value chains under a circular economy approach by applying a scoring system in different subcategories and indicators, considering the plastic packaging sector as a case study. Twelve subcategories have been chosen, because of their relevance to the case study, related to the impacts on the labor conditions, consumers' well-being, end-of-life of the product, local community conditions, technology and suppliers, among others. The validation of the methodology in the plastic packaging sector is done by considering the main stakeholders involved in the value chain and the particularities of the sector. © 2020 by the authors.	Circular economy;Plastic packaging;Product value chain;Social impact assessment;Social life cycle assessment;Sustainability;adaptive management;consumption behavior;economic cycle;environmental impact assessment;life cycle analysis;literature review;packaging waste;plastic;social impact assessment;stakeholder;valuation	10.3390/su12166671
101	Schmidt, S. and Laner, D. and Van Eygen, E. and Stanisavljević, N.	2020	Material efficiency to measure the environmental performance of waste management systems: A case study on PET bottle recycling in Austria, Germany and Serbia	Waste Management	Material efficiency measures, such as recycling rates, are often used to set circular economy targets to achieve higher resource efficiency and lower environmental impact. The aim of this study was to identify material efficiency indicators suitable to reflect the environmental performance of waste and recycling systems using PET bottle waste management in three European countries with diverse waste management structures and recycling performance levels. Material flow analysis and life cycle assessment were performed to assess the material efficiency and environmental impacts of each system as a basis to analyze the relation between these two dimensions. PET bottle waste generation was 5.4 kg/person and year (pa) in Austria in 2013, 6.0 kg/pa in Germany in 2017 and 6.9 kg/pa in Serbia in 2015. Out of this waste flow 41%, 91%, and 11% were directed into PET recyclate in Austria, Germany and Serbia, respectively. For all systems, higher material efficiency translated into lower environmental impact and vice versa. However, linear regression analysis between different material efficiency indicators and environmental impacts showed that indicators targeted at actual recycling, specifically at closed loop, were better suited to reflect environmental performance than input-based indicators. Therefore, whenever data are available, output-based quality-related indicators should be used to measure the material efficiency of waste and resource systems because they correlate best with the goals of increasing resource efficiency and decreasing environmental impacts. © 2020 Elsevier Ltd	LCA;MFA;Packaging waste management;Plastic recycling;Recycling rates;Bottles;Efficiency;Environmental management;Life cycle;Plastic recycling;Regression analysis;Waste management;Environmental performance;European Countries;Life Cycle Assessment (LCA);Management structure;Material efficiency;Material flow analysis;Resource efficiencies;Waste management systems;Environmental impact;environmental impact;life cycle analysis;plastic waste;recycling;regression analysis;waste management;adult;article;Austria;flow measurement;Germany;human;life cycle assessment;linear regression analysis;Serbia;positron emission tomography;Positron-Emission Tomography;Recycling;Waste Management	10.1016/j.wasman.2020.05.011
102	Šerešová, M. and Koci, V.	2020	Proposal of package-	Sustainability (Switzerland)	Today, packaging is an integral part of most foods and beverages. However, excessive and just one-time applications of packaging can bring about indisputable environmental impacts in the form of large amounts of waste generated. If we want	Circular economy;Environmental impacts;Food packaging;Life	10.3390/su12073034

			to-product indicator for carbon footprint assessment with focus on the Czech Republic		to monitor the environmental impacts of packaging materials, it is advisable to assess them in a complex way including not only the specific packaging but also specific products. No universal methodology currently exists that would enable this type of complex assessment regarding the environmental impacts of packaging in relation to particular products. Therefore, the aim of our study was to develop and test a Package-to-Product (PtP) indicator. For this purpose, the life cycle assessment (LCA) was employed to analyse four selected products considering different life cycle stages of packaging and their impacts on the climate change category. The results of the study confirm that the values of the PtP indicator significantly differ for various products, thus emphasising the need to establish a uniform methodology for individual product groups, such as meat, dairy and vegetable products or beverages. The application of this indicator, however, enables a clear impact assessment of different packaging materials and allows the packaging manufacturers to reduce their overall environmental impacts. © 2020 by the authors.	cycle assessment;Package to product;Sustainable development;beverage;carbon footprint;dairy farming;environmental impact assessment;life cycle analysis;manufacturing;meat;packaging waste;vegetable;Czech Republic	
103	Roithner, C. and Rechberger, H.	2020	Implementing the dimension of quality into the conventional quantitative definition of recycling rates	Waste Management	With the proposed Circular Economy Package, the European Union is striving to play a leading role in the implementation of recycling goals. The significantly increased recycling targets are just some of the defined objectives. However, to assess the Member States' attainment of the new recycling targets, the European Union still builds on a purely quantitative recycling rate assessment procedure that neglects to include qualitative recycling aspects. This circumstance could lead to additional quality losses in recycling processes because recyclers might tend to focus exclusively on higher quantities to achieve the stricter recycling targets on time. To prevent such a development, the aim of this study is to establish a complementary recycling indicator that combines quantitative and qualitative recycling aspects in one single metric. The basis of this assessment method is the statistical entropy approach, which enables the concentrating or diluting effect of a recycling process brought about through the separation or mixing of materials to be measured. The results of the statistical entropy metric will provide greater insight into recycling processes (or systems) and thereby yield enhanced information on the quantity and purity of recycling outputs. The simple structure of the new approach will allow enhanced comparisons between technologies as well as national recycling performance. A case study on plastic packaging recycling demonstrates that the new recycling indicator provides multifaceted findings relative to the hitherto purely quantitative recycling assessment data, hence enriching conclusions on the recycling performance. © 2020 Elsevier Ltd	Circular economy;Plastic packaging;Recycling assessment;Recycling effectiveness;Recycling rate;Statistical entropy;Entropy;Circular economy;Plastic packaging;Quantitative definition;Recycling process;Recycling rate;Recycling targets;Simple structures;Statistical entropy;Plastic recycling;European Union;packaging waste;plastic waste;recycling;statistical analysis;waste management;article;economic aspect;entropy;quantitative analysis;packaging;plastic;Plastics;Product Packaging;Recycling;Waste Management	10.1016/j.wasman.2020.02.034
104	Cobo, S. and Levis, J.W. and Dominguez-Ramos, A. and Irabien, A.	2019	Economics of Enhancing Nutrient Circularity in an Organic Waste Valorization System	Environmental Science and Technology	Waste managers struggle to comply with the European legislation that regulates the handling of organic waste. A waste management system that aims at recovering nutrients from the municipal organic waste generated in the Spanish region of Cantabria was modeled by combining material flow analysis, life cycle assessment, and life cycle costing. The model was optimized to find system configurations that minimize the total annual cost (TAC) and the global warming impacts (GW) and maximize the circularity indicators of nitrogen and phosphorus (CI<inf>N</inf> and CI<inf>P</inf>). The developed superstructure is composed of waste management unit processes and unit processes related to the land application of the recovered products (compost, digestate, (NH<inf>4</inf>)<inf>2</inf>SO<inf>4</inf>, and NH<inf>4</inf>MgPO<inf>4</inf>·6H<inf>2</inf>O) and industrial fertilizers to grow corn. The results of the optimization indicate that increasing CI<inf>N</inf> and minimizing GW raises the TAC, because of the investment in new technologies, although high CI<inf>P</inf> values can be achieved at low TACs. The economic margin that enables the organic fertilizers to compete in the market	Composting;Costs;Fertilizers;Global warming;Industrial economics;Life cycle;Managers;Nitrogen compounds;Nutrients;Recovery;European legislation;Global warming impact;Life Cycle Assessment (LCA);Material flow analysis;Nitrogen and phosphorus;System configurations;Waste management systems;Waste management units;Waste management;nitrogen;organic	10.1021/acs.est.8b06035

					with industrial fertilizers was estimated. Cooperation between waste managers, the farmers that purchase the recovered products, and the policy-makers that set the waste management taxes can minimize the costs that hinder the transition toward a circular economy. © 2019 American Chemical Society.	fertilizer;phosphorus;fertilizer;cost analysis;economics;environmental economics;global warming;life cycle analysis;material flow analysis;policy making;waste;waste management;anaerobic digestion;Article;composting;electricity;flow measurement;greenhouse effect;landfill;life cycle assessment;maize;nutrient;organic waste;Cantabria;Spain;Zea mays;Nitrogen;Phosphorus;Waste Management	
105	Tua, C. and Biganzoli, L. and Grosso, M. and Rigamonti, L.	2019	Life cycle assessment of reusable plastic crates (RPCs)	Resources	The European packaging market is forecast to grow 1.9% annually in the next years, with an increasing use of returnable packages. In this context, it is important to assess the real environmental effectiveness of the packaging re-use practice in terms of environmental impacts. This life cycle assessment aims to evaluate the environmental performances of reusable plastic crates (RPCs), which are used for the distribution of 36% of fruit and vegetables in Italy. RPCs can be re-used several times after a reconditioning process, i.e., inspection, washing, and sanitization with hot water and chemicals. The analysis was performed considering 12 impact categories, as well as the cumulative energy demand indicator and a tailor-made water consumption indicator. The results show that when the RPCs are used for less than 20 deliveries, the impacts of the life cycle are dominated by the manufacturing stage. By increasing the number of deliveries, the contribution of the reconditioning process increases, reaching 30-70% of the overall impacts for 125 uses. A minimum of three deliveries of the RPCs is required in order to perform better than an alternative system where crates of the same capacity (but 60% lighter) are single-use. The same modeling approach can be used to evaluate the environmental sustainability of other types of returnable packages, in order to have a complete overview for the Italian context and other European countries. © 2019 by the authors.	Circular economy;Fruit and vegetables;Life cycle assessment (LCA);Packaging system;Re-use;Reusable plastic crates (RPCs)	10.3390/resources8020110
106	Ligthart, T.N. and Thoden van Velzen, E.U. and Brouwer, M.T.	2019	EnvPack an LCA-based tool for environmental assessment of packaging chains. Part 1: scope, methods and inventory of tool	International Journal of Life Cycle Assessment	Purpose: The environmental impact, resource use and waste generation of packaging has been a topic of worldwide debate. This resulted in founding the Netherlands Institute for Sustainable Packaging (KIDV), which aims to facilitate the reduction of these impacts. Within KIDV's scientific programme, an LCA-based tool was developed to show packaging design students the underlying causes of this impact. Researchers can assess packaging chain alternatives with the tool, which is presented in the first part of the paper. Methods: The LCA-based tool, EnvPack, encompassed three consumer products: non-carbonated beverage, shower gel and ready-to-eat soup. Each product had three to four different packaging alternatives. The packaging cradle-to-grave life cycles were defined in terms of materials and processes and included detailed parametrisation of the end-of-life. Packaging-related product losses have been included in EnvPack. For the impact assessment of the product-packaging combinations, four methods were included, each with a different perspective. These were a modified ReCiPe midpoint method, ReCiPe endpoint, cumulative energy demand and a Circular Economy method based on ReCiPe. Packaging for material analysis was collected at Dutch supermarkets. For establishing packaging-related product losses, explorative measurements were made. Microsoft Excel was used to construct	Beverage;Circular economy;Environmental design tool;Packaging;Product loss;Shower gel;Soup;article;beverage;consumer;convenience food;economic aspect;human;human experiment;life cycle stage;Netherlands;nonhuman;scientist;software;student	10.1007/s11367-018-1530-0

					EnvPack. Results and discussion: Researchers and design students can select up to four different packaging alternatives per product, including one self-designed packaging. Packaging-related product losses can be included or not in the assessment. For the beverage, an out-of-home consumption situation can be selected, which affects the end-of-life of the packaging. The contribution of several life cycle stages and of impact categories are presented as graphs for the design students; detailed tables are available for researchers. The tool compares two assessment methods at a time. The effect of different methods on the ranking of the packaging alternatives is a topic of the second part paper. Conclusions: In comparison with existing LCA-based packaging tools, EnvPack includes four different assessment methods that all offer a single score comparison of alternatives. EnvPack is freely available for participating Dutch universities. © 2018, Springer-Verlag GmbH Germany, part of Springer Nature.		
107	Wang, Q. and Gao, Z. and Yuan, X. and Wang, J. and Wang, M.	2019	Comprehensive emergy evaluation and optimization of corn straw power generation system: a case study	Chinese Journal of Population Resources and Environment	Biomass energy has become an important measure to alleviate ecological environment security and energy supply security in China. Emergy accounting method is used to analyze and evaluate economy, environment, and sustainability of corn straw generation system, which includes corn planting subsystem, collection and transportation subsystem, and corn straw power generation subsystem. The key substances that need to be optimized in the system are identified by using sensitivity analysis. Based on the position of key substances in the system, emergy accounting optimization methodology is conducted. Corresponding optimization design scheme is proposed based on the "3R" (reduce, reuse, and recycle) principle of circular economy. Current study shows that emergy yield ratio, emergy investment ratio, environmental loading ratio, and emergy sustainability index of the corn straw power generation system are 3.69, 2.68, 1.61, and 2.29, respectively, which are better than wind power generation system and thermal power generation system. In addition, it is proposed that the fertilizer alternative plan and the transportation redesign plan can replace 50,000 tons potash and reduce equipment resources by 20% and energy resources input by 30%. Economy and sustainable development of the system is significantly improved. The optimization design method based on the "3R" principle proposed in this paper can provide a useful reference for the research in the field of resource recycling. © 2019, © 2019 Shandong Normal University.	Emergy analysis;resource design;sensitivity analysis;sustainable development	10.1080/10042857.2019.1610652
108	Civancik-Uslu, D. and Puig, R. and Ferrer, L. and Fullana–i–Palmer, P.	2019	Influence of end-of-life allocation, credits and other methodological issues in LCA of compounds: An in-company circular economy case study on packaging	Journal of Cleaner Production	The aim of this article is to present a circular economy case study and investigate and discuss effects of end-of-life (EoL) allocation and crediting strategies on the results of this case study. In the case study, replacement of eucalyptus wood sheets, which are used to separate loaded pallets to prevent damaging each other during top storage in the company, by plastic compound alternatives composed of virgin PP, recycled PP and mineral fillers, is studied. When their life time is over, plastic compound sheets are sent to be recycled in the recycling facilities of the company. While performing this comparative LCA, a methodological discussion on how to credit the system in open-loop (OL) and close-loop (CL) recycling is performed. The use of Q factors (quality factors), instead of 1:1 substitution of virgin materials by recycled ones, is recommended and how to define these Q factors is discussed. The use of Q factors based on the mechanical properties of virgin and recycled materials, which is flexural modulus in this case, is recommended. Finally, a formula for the calculation of the Q factor of the compound material leaving the CL recycling after several recycling cycles, is proposed. Results show that, for this case study, plastic compound sheets are environmentally better alternative than eucalyptus wood sheets for most of the environmental impact categories evaluated due to the following reasons: higher number of uses, lower weight, use of recycled PP and mineral fillers, and longer lifetime. However, in two impact categories (resource depletion water and resource depletion mineral, fossils and renewables) eucalyptus wood sheets are found to have slightly better results. For the rest of the impact categories, the difference in	Closed-loop recycling;Environmental credits;Open-loop recycling;Plastics with mineral fillers;Qs/qp;Recycling content and recyclability;Environmental impact;Life cycle;Mechanical properties;Minerals;Natural resources;Plastics fillers;Q factor measurement;Closed loops;Environmental credits;Mineral filler;Open-loop recycling;Qs/qp;Recyclability;Plastic recycling	10.1016/j.jclepro.2018.12.076

					the results are so high that different crediting methods do not affect the results in this case; however, they may in others. Among the scenarios evaluated OL recycling with market mix substitution is found to provide the highest impacts. © 2018 Elsevier Ltd		
109	Pauer, E. and Wohner, B. and Heinrich, V. and Tacker, M.	2019	Assessing the environmental sustainability of food packaging: An extended life cycle assessment including packaging-related food losses and waste and circularity assessment	Sustainability (Switzerland)	Food packaging helps to protect food from being lost or wasted, nevertheless it is perceived as an environmental problem. The present study gives an overview of methods to assess the environmental sustainability of food packaging. Furthermore, we propose a methodological framework for environmental assessment of food packaging. There is a broad consensus on the definition of sustainable packaging, which has to be effective, efficient, and safe for human health and the environment. Existing frameworks only provide general guidance on how to quantify the environmental sustainability of packaging. Our proposed framework defines three sustainability aspects of food packaging, namely direct environmental effects of packaging, packaging-related food losses and waste, as well as circularity. It provides a list of key environmental performance indicators and recommends certain calculation procedures for each indicator. The framework is oriented towards the Product Environmental Footprint initiative and the Circular Economy Package of the European Union. Further research should develop a method to determine the amount of packaging-related food losses and waste. Moreover, future studies should examine the potential environmental benefits of different measures to make food packaging more circular. © 2019 by the authors.	Circular economy;Environmental sustainability;Food losses and waste;Food packaging;Life cycle assessment;Sustainability framework;economic structure;environmental assessment;environmental impact;food;food waste;life cycle analysis;packing;sustainability	10.3390/su11030925
110	Franco-García, M.-L. and Haanstra, W. and Toxopeus, M. and Schuur, B.	2019	Social and Environmental Life Cycle Assessment (SELCA) Method for Sustainability Analysis: The Jeans Global Value Chain as a Showcase	Greening of Industry Networks Studies	In this chapter the concepts of social life cycle assessment and combined social and environmental LCA were explored through the application of existing LCA methods to the global value chain of jeans. The social and environmental life cycle assessment (SELCA) method resulted from this explorative research that aims to contribute to the battery of impact assessment tools of products whose value chain scope is multinational (global). From a broader perspective, SELCA has a double-folded purpose to (i) identify opportunities for environmental and social improvement at any of the value chain phases of products, for remediation goals, and (ii) predict the environmental and social performance of different ways (scenarios) to produce the same product, using it as a product design tool. To simplify SELCA development, it was decided to use a single product (jeans) as a showcase from the global textile sector. In this showcase, four scenarios for jeans assembly were compared; three of them were defined under the circular economy principles by including recycled materials (cotton, PET and nylon 6) during the yarn production. During the application of the SELCA method, some new challenges were encountered related to inventory analysis, in particular during data acquisition for social inventories. This is later mainly due to the extensive list of key stakeholders for the showcase and the qualitative nature of social metrics. This list starts with cotton cultivators from different countries where regulations and codes of conduct seem to have contextualised interpretations and consequently different levels of implementation. In this regard, governmental intervention to instrument the transition towards suitable social/environmental performance along the global jeans value chain was also discussed in this chapter. © 2019, Springer International Publishing AG, part of Springer Nature.	Circular economy;Combined social and environmental life cycle assessment;Global value chain;Jeans;SELCA;Stakeholders	10.1007/978-3-319-92931-6_11

111	Puyuelo, B. and Arizmendiarrieta, J.S. and Irigoyen, I. and Plana, R.	2019	Quality assessment of composts officially registered as organic fertilisers in Spain	Spanish Journal of Agricultural Research	Composting of organic wastes is a management strategy linked to circular economy models through the transformation of these wastes into an organic product, compost, which can be used as fertiliser, soil amendment or growing media. However, the concept of 'compost quality' is not enough defined to take a technical decision about which is its best use or application. In the last decade, different guidelines and regulations about organic fertilisers have been developed. For instance, in Spain the Fertilisers Regulation categorises compost under five kinds according to the raw materials used - organic amendment compost (OaC), manure compost (MaC), green compost (GrC), vermicompost (VC), 'alperujo' compost (AlC) -, and under three quality levels (A, B or C) depending exclusively on the heavy metals content. This work analyses the national database of all composts (307) marketed in Spain, considering the analytical parameters declared, with the objective of proposing a methodology to define a global quality index. For this assessment, two indicators are employed: a fertility indicator, related to the nutrients content, and a clean indicator, related to the heavy metals content. Results show an average compost formulation 2.5:2.5:2.5 (N:P <inf>2</inf> O <inf>5</inf> :K <inf>2</inf> O). MaC and OaC present the highest fertility indicator, whereas VC the lowest. Regarding the clean indicator, GrC, MaC and VC are cleaner than OaC. In the future, this new quality assessment should be completed by including other indicators related to physical and biological characteristic (e.g. porosity, stability/maturity, phytotoxicity) that could determine the most proper use of compost. © 2019 INIA.	Clean indicator;Compost quality;Fertility indicator;Heavy metals;Macronutrients;Maturity	10.5424/sjar/2019171-13853
112	Schmidt Rivera, X.C. and Leadley, C. and Potter, L. and Azapagic, A.	2019	Aiding the design of innovative and sustainable food packaging: Integrating techno-environmental and circular economy criteria	Energy Procedia	Reducing food waste and increasing resource efficiency have become worldwide targets as highlighted by the United Nations Sustainable Development Goal 12 - Responsible consumption and production. Food packaging, in particular plastics-based, is a key component of food-related waste: packaging increases the amount of total waste, but also reduces potential food waste by protecting food products and prolonging their shelf life. Therefore, it is important that packaging is designed as to satisfy both technical and environmental criteria. Hence, this paper seeks to develop a decision-support framework and key metrics to aid development and selection of new innovative food packaging within a circular economy context. A set of indicators is proposed, integrating techno-environmental and circular economy criteria to help designers as well as food and packaging manufacturers develop more sustainable products. The methodology is illustrated through a prototype new plastic packaging developed as part of this project, considering its use for two types of product - raspberries and meat - as illustrative examples. © 2019 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0/)	Climate change;Environmental impacts;Food waste;Life cycle assessment;Plastics;Resource efficiency;Climate change;Decision support systems;Elastomers;Energy conservation;Environmental impact;Food products;Life cycle;Packaging;Packaging machines;Plastics;Circular economy;Decision support framework;Food waste;Life Cycle Assessment (LCA);Packaging manufacturers;Plastic packaging;Resource efficiencies;Sustainable products;Sustainable development	10.1016/j.egypro.2019.02.081
113	Niero, M. and Kalbar, P.P.	2019	Coupling material circularity indicators and life cycle based indicators: A proposal to	Resources, Conservation and Recycling	The debate on the identification of the most suited metrics for circular economy (CE) is open, no consensus has been reached yet on what CE indicators at product level should measure, which creates a subjective methodological framework for assessing CE strategies. In this study, we demonstrate that by coupling different types of indicators via Multi Criteria Decision Analysis (MCDA) it is possible to deal with conflicting situations where the selection of the best alternative can be biased by the choice of the metric. We use a beer packaging case, by simulating a situation where a company is interested in comparing the performances of different packaging from a CE perspective. We consider eight different beer packaging alternatives in two geographical contexts (United Kingdom and India). Two sets of indicators are coupled via MCDA: i) material circularity based- indicators, namely Material Reutilization Score and Material Circularity Indicator, and ii) a selection	Circular economy;Circularity indicators;Life cycle assessment;Multi criteria decision analysis;Packaging;TOPSIS;Beer;Climate change;Decision making;Packaging;Circular economy;Coupling materials;Life Cycle Assessment (LCA);Methodological	10.1016/j.resconrec.2018.10.002

			advance the assessment of circular economy strategies at the product level		of life cycle based- indicators relevant for beer, i.e. climate change, abiotic resource depletion, acidification, particulate matter and water consumption. The results obtained by the application of the TOPSIS (Technique for Order by Similarity to Ideal Solution) method show that the different sets of indicators can be integrated and conflicts among them can be resolved. Overall, the application of different weighting scenarios does not change the ranking of the alternatives, thus confirming that the results are stable. Therefore, our proposal of coupling material circularity indicators with LCA indicators via MCDA can advance the assessment of CE strategies at the product level. © 2018 Elsevier B.V.	frameworks;Multi-criteria decision analysis;Particulate Matter;Resource depletion;TOPSIS;Life cycle;assessment method;environmental economics;life cycle analysis;multicriteria analysis;strategic approach;acidification;article ;beer;climate change;economic aspect;fluid intake;India;life cycle assessment;particulate matter;United Kingdom	
114	Cornago, Simone and Rovelli, Davide and Brondi, Carlo and Crippa, Maurizio and Morico, Barbara and Ballarino, Andrea and Dotelli, Giovanni	2021	Stochastic consequential Life Cycle Assessment of technology substitution in the case of a novel PET chemical recycling technology	JOURNAL OF CLEANER PRODUCTION			10.1016/j.jclepro.2021.127406
115	Van Roijen, Elisabeth C. A. and Miller, Sabbie A.	2022	A review of bioplastics at end-of-life: Linking experimental biodegradation studies and life cycle impact assessments	RESOURCES CONSERVATION AND RECYCLING			10.1016/j.resconrec.2022.106236
116	Saxegard, Simon A. and Williams, Helen and	2025	Life cycle assessment of reduce, recycling	INTERNATIONAL JOURNAL OF LIFE CYCLE ASSESSMENT			10.1007/s11367-025-02548-2

	Wikstrom, Fredrik		and final treatment of plastic primary food packaging in Norway using a system expansion with multiple functions scope				
117	Hirata, Kazuma and Kata, Daiki and Nakatani, Jun	2025	How does future decarbonization in industries affect the climate benefits of plastic recycling? A market share-based model for the avoided burden approach of life cycle assessment	RESOURCES CONSERVATION AND RECYCLING			10.1016/j.resconrec.2025.108305
118	Lofthouse, V. and Trimingham, R. and Bhamra, T.	2017	Reinventing refills: guidelines for design	Packaging Technology and Science	This paper draws on the findings of a Department for Environment and Rural Affairs funded collaborative research project run by the Loughborough Design School in collaboration with Boots Alliance GmbH and presents guidelines for design teams regarding the design of successful, sustainable, refillable packaging. The study focused on “body wash” products in the area of personal care. A broad range of qualitative methods were used to create a background framework, develop design concepts, and test the viability of the design solutions. Two concepts were turned into high-fidelity prototypes and tested in multi-activity user focus groups. The prototypes were also evaluated from an environmental perspective using the Eco Indicator 99. Discussion is focused around general findings regarding refillable packing and also on specific findings related to “concentrates mixed in the parent pack.” The findings from this study have dramatically increased levels of understanding about the potential implications of refillable packaging and how it might be successfully used by business. A range of guidelines for the design of refills have been identified, which help to build a clearer picture of the requirements of successful refillable packaging design. Additionally, a much more	circular economy;ecodesign;personal care;product development;refillable packaging;user centred;Chemistry;Ecodesign;Product development;Business challenges;Circular economy;Collaborative research projects;Consumer perception;Environmental needs;Personal care;Qualitative method;User-	10.1002/pts.2337

					detailed understanding of consumer perceptions, business challenges/opportunities, and environmental savings associated with "concentrated refills that are mixed in the parent pack," has been identified. It has been seen that to be successful refills must perform for the consumer, the environment, and business, and although this may sound unsurprising, it is challenging to achieve. It means they must offer good quality; be very easy to use and appropriately delivered; be clearly communicated; be offered through a brand consumers like; and represent good value, whilst radically reducing the amount of packaging manufactured and distributed. Incorporating carefully considered consumer and environmental needs into the brief is critical to the successful development of refillable packaging. © © 2017 John Wiley & Sons, Ltd.	centred;Packaging;Product Development	
119	Molina-Moreno, V. and Leyva-Díaz, J.C. and Llorens Montes, F.J. and Cortés-García, F.J.	2017	Design of indicators of circular economy as instruments for the evaluation of sustainability and efficiency in wastewater from pig farming industry	Water (Switzerland)	Circular economy intends to turn waste into resources that can be reintroduced into the production process, eliminating the negative externalities from it. The impact of pig manure on the environment is one of the main challenges in agriculture. The high amount of pig manure coming from the pig farming industry complicates the management of this type of effluents, leading to a serious impact on the environment, as it pollutes the soil, the water, and the air. The concept of the indicator of circular economy was introduced to evaluate the degree of approximation of the pig manure treatment process to the circular economy model. In light of this, these indicators showed the possibility of obtaining 0.97 m3 water h-1, 49.40 kg biofertilizer h-1, and 5.33 m3 biogas h-1 per 1 m3 pig manure h-1 treated, allowing us to assess the minimization of waste generation and the efficiency of the use of resources. By applying an anaerobic digestion process to treat pig manure, reductions of water and natural gas consumptions were 47.01% and 5.33%, respectively, which leads to a reduction in emissions of 171.98 kg CO<inf>2</inf> h-1. Consequently, pig manure can be considered as a technological nutrient that is reintroduced into the productive system, enabling the recovery of energy, water, and biofertilizer contained therein. © 2017 by the authors.	Circular economy;Energy;Indicator;Pig manure;Technological nutrient;Wastewater;Anaerobic digestion;Economics;Effluents;Fertilizers;Gas emissions;Indicators (instruments);Manures;Nutrients;Sustainable development;Wastewater;Anaerobic digestion process;Circular economy;Degree of approximation;Energy;Impact on the environment;Negative externalities;Pig manures;Recovery of energies;Industrial economics;anaerobic digestion;design method;economic instrument;emission control;energy efficiency;environmental economics;environmental impact assessment;environmental indicator;industrial waste;resource use;sustainability;technological change;wastewater treatment;Suidae	10.3390/w9090653
120	Niero, M. and Hauschild, M.Z.	2017	Closing the Loop for Packaging: Finding a Framework to Operationalize	Procedia CIRP	This paper examines some of the most common frameworks available to companies in implementing circular economy strategies, i.e. the Cradle-to-Cradle design protocol, the Material Circularity Indicator and the Life Cycle Sustainability Assessment framework intended as a combination of Life Cycle Assessment, Environmental Life Cycle Costing and Social Life Cycle Assessment. We focus on the packaging sector and use the case of closed-loop aluminium can supply to illustrate the benefits and limitations of combining some of these frameworks. Our recommendation is to use the Life Cycle Sustainability Assessment framework to evaluate circularity strategies, since it is the most	aluminum;circularity;cradle to cradle;environmental Life Cycle Costing;Life Cycle Assessment;Life Cycle Sustainability Assessment;life cycle thinking;material circularity indicator;Social LCA;Aluminum;Network function	10.1016/j.procir.2016.11.209

			Circular Economy Strategies		comprehensive and still operational framework and best at preventing burden shifting between stakeholders in the value chain. © 2017 The Authors.	virtualization;Sustainable development;circularity;Cradle to cradles;Environmental life cycle;Life Cycle Assessment (LCA);Life cycle sustainability assessments;Life cycle thinking;Social LCA;Life cycle	
121	Smol, Marzena and Kowalski, Zygmunt and Makara, Agnieszka and Henclik, Anna	2019	Comparative LCA study of different methods of the feed phosphates (FPs) production	JOURNAL OF CLEANER PRODUCTION			10.1016/j.jclepro.2019.117963
122	Moresi, Mauro and Cimini, Alessio	2025	Streamlined life cycle assessment of packaging waste in coffee preparation and consumption	ITALIAN JOURNAL OF FOOD SCIENCE			10.15586/ijfs.v37i4.3256
123	Rincon, Paula M. and Renner, Manfred and Borchardt, Lars and Biessey, Philip	2025	Process development and prospective life-cycle assessment of the mechanochemical depolymerization of polyethylene terephthalate	CHEMICAL ENGINEERING JOURNAL			10.1016/j.cej.2025.161411
124	Abejon, R. and Bala, A. and Vazquez-Rowe, I and Aldaco, R.	2020	When plastic packaging should be preferred:	RESOURCES CONSERVATION AND RECYCLING			10.1016/j.resconrec.2019.104666

	and Fullana-i-Palmer, P.		Life cycle analysis of packages for fruit and vegetable distribution in the Spanish peninsular market				
125	de Anda-Rodriguez, Flavio A. and Corona-Ramirez, Mariana R. and Patino-Arevalo, Carlos D. and Zarate-Navarro, Marco A. and Zarate-Guzman, Ana I. and Romero-Cano, Luis A.	2025	Mycomaterials from Agave Bagasse: A Valorization Strategy for Sustainable Tequila Packaging	FERMENTATION-BASEL	A sustainable strategy is proposed for the valorization of solid waste from the Tequila industry through the development of bio-packaging for Tequila bottles using mycelium from Ganoderma lucidum. The fungus was isolated from Bosque de la Primavera (Jalisco, Mexico) and cultivated on lignocellulosic substrates: agave bagasse and corn stover. These agricultural residues were dried, ground, and pasteurized to optimize their performance as growth media. Their structural integration before and after fermentation was evaluated using optical microscopy. The high cellulose and hemicellulose content of both substrates supported robust mycelial development, enabling the formation of moldable materials through solid-state fermentation. After growth, the mycelium colonized the substrate, forming a functional mold adapted to the geometry of a Tequila bottle prototype. The molded parts were dried to halt fungal activity, prevent fruiting, and stabilize the structure. Physical and mechanical characterization showed competitive performance with regard to bulk density (0.11 +/- 0.1 g cm-3), water absorption (78.1 +/- 4.2%), and high impact resistance (evaluated via Solidworks simulation). A life cycle assessment revealed that mycelium packaging has a significantly lower environmental impact than expanded polystyrene. The material supports circular economy principles within the Tequila production chain. PU - MDPI PI - BASEL PA - MDPI AG, Grosspeteranlage 5, CH-4052 BASEL, SWITZERLAND		10.3390/fermentation11090500
126	Arias, A. and Ribeiro, J.M. and Tsalidis, G. and Renfrew, D. and Dias, D. and Avramidi, M. and Kyriazi, M. and Moreira, M.T. and Katsou, E.	2025	Urban wastewater treatment plants as resource hubs: evaluating circularity and sustainability of nutrient recovery and water reuse	Water Research	Wastewater treatment plants (WWTPs) are evolving from pollution control facilities into resource recovery hubs, aligning with circular economy principles. However, assessing their transition requires robust methodologies that integrate environmental, economic, and circularity dimensions. This study aims to evaluate the sustainability and circularity performance of a WWTP in Cyprus upgraded with additional treatment stages to recover nutrient-rich sludge for fertilizer and treated water for irrigation. To achieve this, a combined methodological framework was applied, incorporating standardized Circularity Assessment (based on ISO 59,004), Life Cycle Assessment (LCA), and Life Cycle Costing (LCC). Circularity was assessed using a dual-indicator approach: “resource flow indicators” (covering material, energy, and economic flows) and “circular actions indicators” (capturing process optimization, repurposing, cascading, and regeneration). Environmental and economic impacts were quantified using LCA and LCC, respectively, while sensitivity analyses explored the effects of renewable energy integration and process simplification. Results show that while the upgraded WWTP enhances circularity through increased resource recovery and high-value product generation, it also incurs higher environmental impacts and operational costs due to energy-intensive technologies (distillation, reverse osmosis, and nanofiltration), increasing the impacts in values that can achieve +60 % in some impact categories. Sensitivity scenarios demonstrated that reducing energy demand and increasing renewable energy use can improve sustainability outcomes, with the higher average impact reduction achieving -20 %, though often	Circularity indicators;Life cycle analysis;Resource recovery;Scenario analysis;Treated wastewater reuse;Circular economy;Costs;Ecodesign;Economic analysis;Economic and social effects;Energy policy;Environmental technology;Life cycle;Life cycle assessment;Nutrients;Pollution control;Sensitivity analysis;Sustainable development;Wastewater treatment;Circularity indicator;Energy;Life cycle analysis;Life cycle costing;Performance;Resource recovery;Scenarios analysis;Treated wastewater reuse;Waste water treatment	10.1016/j.watres.2025.124406

					at the expense of circularity performance. The study highlights the trade-offs between maximizing resource recovery and minimizing environmental and economic burdens, emphasizing the need for optimized process design and supportive policy frameworks to enable WWTPs to function as effective circular economy enablers. The findings show that advanced treatment technologies enhance circularity through increased resource recovery, but also entail elevated energy demands and limited economic viability. While frameworks like ISO 59,004 support multidimensional assessment, further methodological development is needed to guide sustainable decision-making. © 2025	plants;Wastewater reclamation;fertilizer;life cycle analysis;nutrient dynamics;recovery;scenario analysis;sustainability;urban area;wastewater treatment plant;water use;Article;chlorination;crystallization;decision making;disinfection;distillation;effluent;energy consumption;energy demand;environmental impact;environmental indicator;environmental sustainability;life cycle;life cycle assessment;nanofiltration;nutrient management;performance indicator;process design;process optimization;recycling;renewable energy;reverse osmosis;salinity;sludge;soil salinization;valorization;waste water recycling;waste water treatment plant;water content;water quality;city;procedures;sewage;wastewater;water management;Cities;Fertilizers;Recycling;Sewage;Waste Disposal, Fluid;Wastewater;Water Purification	
127	Katiyar, A. and Gedam, V.V.	2025	The circular economy and fertilizer industry: a systematic review of principal measuring tool	Environment, Development and Sustainability	The fertilizer industry (FI) plays a crucial role in the global food supply chain to satisfy the needs of a growing population. However, the increasing use of fertilizers has a detrimental effect on the ecosystem. To combat this problem, industries have been using the traditional linear economy model. This model works on the principle of “take, make, use, dispose.” Despite this, there is a growing concern among the masses about the global waste crisis. Hence, a new and more sustainable approach has caught the attention of stakeholders—the circular economy (CE) model. The life cycle assessment (LCA) methodology is used by a number of industries to determine and evaluate the inputs and outputs of multiple activities carried out in a linear economy model. However, it is equally crucial for the LCA to incorporate into its framework the circularity relationship of resources. As more and more industries in developing nations are transitioning from the linear economy to the CE model, taking this relationship into account becomes all the more important. However, there is still a dearth of the literature that incorporates the circularity components of FI into the LCA framework. The current study aims to support the CE initiatives by presenting the systematic and bibliometric analysis of the overall development of the application of LCA. It is imperative to switch out the current LCA implementation with a more effective method that captures the worth of the resources that are reused, recycled,	Circular products;Experiences and good practices;Product environmental footprint;Product recovery;Regeneration;System thinking;carbon footprint;circular economy;decision making;fertilizer;industrial technology;life cycle analysis;literature review;stakeholder;strategic approach	10.1007/s10668-024-04518-4

					remanufactured, and repurposed. Additionally, the strategy must record the potential upstream and downstream impacts to make sustainable decisions. To achieve this, the study identifies the limitations and challenges of applying LCA to a CE model in the FI. This is done by applying the Boolean search criteria using Boolean operators: AND, OR, and NOT. Thus, to highlight scholarly trends, the study explores key contributors and contemporary dynamics, analyzes CE-LCA relationship in FI, and suggests possibilities of circular strategies for the future. The study will act as a multidisciplinary road map to resolve the current research challenges while considering the potential future trends to assist academic and industry professionals. The study also offers policy and managerial insights enabling policy and decision-makers of the FI to understand the effectiveness of the CE-LCA framework. © The Author(s), under exclusive licence to Springer Nature B.V. 2024.		
128	Renfrew, D. and Vasilaki, V. and Nika, E. and Harris, E. and Katsou, E.	2024	Tracing wastewater resources: Unravelling the circularity of waste using source, destination, and quality analysis	Water Research	Current circularity assessment terminology restricts application to wastewater processes due to the focus on technical systems. Waste stream and wastewater discharge circularity definitions lead to paradoxical assessments that generate results of little value for evidence-based decision making. Therefore, a classification approach was developed to measure inflow and outflow circularity of the main wastewater resource flows using the principle of traceability, adopting the attitude that not all waste is created equally. Applying it to a wastewater treatment plant (12,000 m3/d load) showed how upstream agricultural, industrial, and human practices impact downstream treatment, and the effectiveness of resource cycling within the natural environment. Industrial actions increasing fossil carbon concentration (400 m3/d effluent at 1000 mgC/l) reduced inflow and outflow circularity by 16 % and 10.6 % respectively, as secondary and sludge treatment fossil emissions increase significantly. Alternatively, changes to human and agricultural practices (50 % reduction of detergent and synthetic fertiliser usage) improved phosphorus inflow and nitrogen outflow circularity by 5.2 % and 20.1 % respectively. This approach can educate and assign responsibility to water users for developing robust circular economy policy, shifting the pattern from promoting circularity to discouraging linear actions, overcoming the shared economic and environmental burden of linear water use. © 2023	Assessment indicators;Circular economy;Circularity assessment;Material flow analysis;Resource traceability;Decision making;Effluent treatment;Fertilizers;Industrial water treatment;Quality control;Rivers;Wastewater treatment;'current;Agricultural practices;Assessment indicator;Circular economy;Circularity assessment;Human practices;Materials flow analysis;Resource traceability;Technical systems;Waste stream;Effluents;biogas;carbon;nitrogen;phosphorus;sea water;water;detergent;discharge;effluent;outflow;wastewater treatment;wastewater treatment plant;activated sludge;Article;atmospheric deposition;biosolid;carbon cycling;carbon emission;carbon source;energy consumption;environmental policy;flow measurement;fractionation;human;incineration;landfill;nutrient cycling;nutrient management;recycling;sewage treatment;sludge;sludge treatment;waste water management;water cycle;water flow;procedures;sewage;wastewater;Humans;Nitrogen;Se	10.1016/j.watres.2023.120901

						wage;Waste Disposal, Fluid;Wastewater;Water	
129	Mazzoli, Enrico and Parashar, Abhijit and D'Odorico, Paolo and Branca, Giacomo	2024	Greening the city: A holistic assessment of waste management alternatives in India.	The Science of the total environment			10.1016/j.scitotenv.2024.176894
130	Cowan, N. and White, S. and Olszewska, J. and Dobel, A. and Sim, G. and Eades, L.J. and Skiba, U.	2022	Integration of algae treatment with hydroponic crop waste to reduce impact of nutrient waste streams	Journal of Sustainable Agriculture and Environment	Introduction: Controlled environment agriculture (CEA) is expanding globally, but little is known about nutrient losses within these systems, or how to reduce subsequent pollution. This experiment investigates the potential to treat wastewater from hydroponically produced lettuce via the application of algae. Materials and Methods: A total of 132 heads of lettuce were produced in the 4-layer nutrient film technique (NFT) vertical farming rack. Waste from the hydroponic system was used to cultivate naturally occurring algae. Nitrogen (N), phosphorus (P) and other trace elements (Ca, Co, Cu, Fe, K, Mg, Mn, Mo, Ni and Zn) were measured at each stage of production. Results: Overall the nutrient use efficiency (NUE) of applied mineral nitrogen (N) and phosphorus (P) was 88.7% and 59.4%. After algae treatment of waste streams the full system NUE of N and P was 99.5% and 95.0% respectively, thus significantly reducing waste heading for sewage. It was found that the crops consumed large quantities of Ca, Cu, Fe and Zn from the rooting sponges used in this experiment, which may have become available due to mineralization and the presence of slightly acidic fertiliser solution. The overall waste produced by the rooting sponge is of concern regarding the full NUE of the system, accounting for approximately 53% and 6% of the total N and P input into the system. Conclusions: This study highlights that treating wastewater streams from controlled environment agriculture (CEA) methods such as hydroponics with algae is successful and easy to achieve with little effort. Future efforts by researchers and the CEA industry to better manage nutrient streams is recommended to improve the environmental credentials of developing CEA systems. © 2022 The Authors. Journal of Sustainable Agriculture and Environment published by Global Initiative of Crop Microbiome and Sustainable Agriculture and John Wiley & Sons Australia, Ltd.	circular economy;controlled environment agriculture;nitrogen;phosphorus;vertical farming	10.1002/sae2.12025
131	Lima, P.D.M. and Lopes, T.A.D.S. and Matos Queiroz, L.M. and McConville, J.R.	2022	Resource-oriented sanitation: Identifying appropriate technologies and environmental gains by coupling Santiago software and life	Science of the Total Environment	Implementation of resource recovery technologies is becoming increasingly important, as humans are exhausting the world's natural resources. Recovering nutrients and water from wastewater treatment systems will play an important role in changing the current trends towards a circular economy. However, guidance is still needed to determine the most appropriate way to do this. In this study two decision-support tools, sanitation planning software (Santiago) and life cycle assessment (LCA), were applied to identify appropriate technologies and their environmental impacts. As a case study, current and alternative scenarios for a wastewater treatment plant (WWTP) in Campo Grande, west-central Brazil, were used. Among 12 scenarios provided by Santiago for efficient nutrient recovery, eight were selected for further assessment. The current WWTP system (UASB reactors) resulted in the highest negative impacts in two of nine assessment categories (freshwater and marine eutrophication), due to nutrient discharge to water. A source separation scenario with urine stored in a urine bank and co-composting of feces showed best overall performance. Electricity consumption played a crucial role for impacts in several categories, while water consumption was not significantly affected by choice of toilet. One Santiago scenario matched	Decision-making;Environmental burden;Nutrient recovery;Wastewater treatment plant (WWTP);Anaerobic digestion;Decision support systems;Environmental management;Environmental technology;Eutrophication;Life cycle;Nutrients;Sanitation;Sewage pumping plants;Source separation;Wastewater reclamation;Wastewater treatment;Water conservation;Water treatment	10.1016/j.scitotenv.2022.155777

	cycle assessment in a Brazilian case study	the most appropriate scenario with the best environmental performance, but the other seven scenarios were not as beneficial, indicating a need for some adjustments in the software. These results highlight the importance of performing LCA to compare alternative scenarios, even when using a tool designed to identify locally appropriate technologies. The results also indicate that the current wastewater treatment system has reasonable environmental performance, but could be improved if measures were taken to recover energy and reuse water. © 2022 The Authors	plants;'current;Appropriate technologies;Case-studies;Decisions makings;Environmental burdens;Environmental performance;Nutrient recovery;Waste water treatment plants;Wastewater treatment plant;Wastewater treatment system;Decision making;ammonia;biogas;carbon dioxide;ferric chloride;fertilizer;fresh water;methane;nitrogen;onsite biogas;phosphorus;silicone;solid fertilizer;unclassified drug;water;decision making;environmental impact;environmental technology;life cycle analysis;nutrient;sanitation;software;wastewater treatment plant;agronomics;algorithm;Article;biogas production;biosphere;Brazilian;chemical oxygen demand;climate change;clinical decision support system;comparative study;distillation;efficient nutrient recovery;electricity;energy consumption;environmental gain;environmental impact assessment;environmental performance;environmental reclamation;environmental sanitation;Eucalyptus;eutrophication;fluid intake;freshwater ecotoxicity;freshwater eutrophication;global warming potential;greenhouse effect;greywater treatment;groundwater depth;health care planning;Horizontal subsurface flow constructed wetland;human;human carcinogenic toxicity;irrigation (agriculture);life cycle assessment;Monte Carlo

						method;nitrification;nonhuman;nutrient discharge;pasteurization;plantation;population density;reproducibility;resource oriented sanitation;sensitivity analysis;sludge management;soil analysis;soil emission;technology;temperature;terrestrial ecotoxicity;waste water treatment plant;water content;water supply;animal;Brazil;life cycle stage;procedures;sewage;wastewater;Animals;Humans;Life Cycle Stages;Software;Waste Disposal, Fluid;Waste Water;Water	
132	Priya, E. and Jha, Akash and Paghadal, Jatin C. and Sarkar, Sudipta	2025	Insect-derived chitosan for phosphate recovery and application as a sustainable fertilizer	ENVIRONMENTAL RESEARCH			10.1016/j.envres.2025.122252
133	Patil, Hrishikesh and Naik, Ravindra and Paramasivam, Suresh Kumar	2024	Utilization of banana crop ligno-cellulosic waste for sustainable development of biomaterials and nanocomposites	INTERNATIONAL JOURNAL OF BIOLOGICAL MACROMOLECULES			10.1016/j.ijbiomac.2024.137065
134	Ncube, A. and Fiorentino, G. and	2021	Upgrading wineries to	SCIENCE OF THE TOTAL ENVIRONMENT			10.1016/j.scitotenv.2021.145809

	Colella, M. and Ulgiati, S.		biorefineries within a Circular Economy perspective: An Italian case study				
135	Barcelos, SMBD and Salvador, R and Barros, MV and de Francisco, AC and Guedes, G and Barcelos, Silvia Mara Bortoloto Damasceno and Salvador, Rodrigo and Barros, Murillo Vetroni and de Francisco, Antonio Carlos and Guedes, Graca	2021	Circularity of Brazilian silk: Promoting a circular bioeconomy in the production of silk cocoons	JOURNAL OF ENVIRONMENTAL MANAGEMENT	The bioeconomy is considered one of the three main sectors with the greatest opportunities for the development of the circular economy in Brazil, who is one of the largest silk producers in the world; and sericulture is an agribusiness that contributes greatly to the bioeconomy in Brazil. Therefore, this research aimed to identify opportunities for creating value by internalizing flows in the production of silk cocoons by promoting a circular bioeconomy. To that end, a tool was used to assess the circularity of the referred system. The current circularity of the production of silk cocoons, at the farm level, is 74.19 % for material, and 0 % for energy. A range of measures are proposed, based on (i) engaging with reverse logistics practices, (ii) establishing a local agroindustrial cooperative, and (iii) building community biodigesters, which aid a potential circularity of 85.51 % (material), and 100 % (energy) at the farm level, and 98.42 % (material) and 100 % (energy), at the cooperative level. On top of increasing circular value, the proposed measures might bring environmental benefits, such as lessening environmental impacts of logistics (by valuing local resources) and replacing non-renewable energy, and social impacts, through increased quality of life for sericulturists. Economic implications need further investigation and are suggested to be addressed in future research endeavors, along with policy implications for the development of a circular bioeconomy. Furthermore, an increased circularity can also contribute to a few of the sustainable development goals (SDGs) proposed by the United Nations, such as SDGs 2, 7, 9, 11, 12 and 13.	ELECTRICITY;PLANTS;BIOGAS;ROUTE;SITES	10.1016/j.jenvman.2021.113373
136	Goncalves, M and Freire, F and Garcia, R and Goncalves, Mariana and Freire, Fausto and Garcia, Rita	2021	Material flow analysis of forest biomass in Portugal to support a circular bioeconomy	RESOURCES CONSERVATION AND RECYCLING	A comprehensive understanding of how resources are utilized is required to support a circular bioeconomy. This article presents the first systematic assessment of forest biomass flows and stocks in Portugal and analyzes circularity and resource efficiency through a comprehensive set of indicators, while providing recommendations for their use and improvement in different contexts. A Material Flow Analysis was developed for 2015, including paper, wood panels, furniture, carpentry, packaging, other wood work, and energy (firewood, pellets, charcoal, electricity, heat), addressing uncertainty. Material flow analysis indicators (e.g., domestic material consumption) and circularity/resource efficiency indicators (cascade factor, material circularity indicator, recycled input, recovery rate) were assessed. In 2015, 49% of forest biomass was used for energy and 51% for material production. The wood sector in Portugal is heterogeneous regarding circularity. Paper and wood packaging were the most recycled products (highest material circularity indicator: 0.49 and recovery rate: 54%), while the panels sector used the most industrial residues (highest cascade factor: 3.78). The indicators analyzed provided a complementary assessment of circularity, giving both system wide (cascade factor) and sector- (cascade factor, recycled input rate, recovery rate) or product-based (material circularity indicator) views. Cascade factor permits an analysis of the whole system and of separate sectors, and an assessment of post-consumer and industrial residues, and both material and energy use.	MATERIAL CYCLES;QUANTIFICATION;Portugal	10.1016/j.resconrec.2021.105507

					Material circularity indicator considers closed- and open-loop recycling of post-consumer residues, being complementary to the cascade factor. Indicators providing complementary perspectives are important to capture multiple types of resource use and valorization within the bioeconomy system.		
137	Rufi-Salis, M and Petit-Boix, A and Villalba, G and Gabarrell, X and Leipold, S and Rufi-Salis, Marti and Petit-Boix, Anna and Villalba, Gara and Gabarrell, Xavier and Leipold, Sina	2021	Combining LCA and circularity assessments in complex production systems: the case of urban agriculture	RESOURCES CONSERVATION AND RECYCLING	Local food production through urban agriculture (UA) is promoted as a means to make cities more sustainable. However, UA does not come free of environmental impacts. In this sense, optimizing urban resources through circular economy principles offers the opportunity to close loops and improve production systems, but an assessment of these systems through a combination of circularity and environmental tools is missing from the literature. The goal of our study is to analyse the environmental and circularity performance of applying circular strategies in UA systems. We use Life Cycle Assessment (LCA) and the Material Circularity Indicator (MCI) to assess the baseline scenario of a Mediterranean rooftop greenhouse and the application of 13 circular strategies. The results show that the MCI score for all strategies was biased by overweighting of the water subsystem in the mass balance. Based on this finding, we propose a series of modifications to the circularity assessment, calculating specific MCI scores for every subsystem before coupling them with environmental life cycle indicators. The outcome is a set of indicators that use the Linear Flow Index (LFI), where decreasing the values as much as possible will correspond to a decrease both in environmental impact and linearity of the system (the inverse of circularity). The use of these indicators provides a simple understanding of the circular and environmental performance of these systems while being fully adaptable. With these indicators, the uses of nutrient recirculation, struvite fertilizer or recycled materials were the best strategies to improve urban agriculture.	LIFE-CYCLE ASSESSMENT;ENVIRONMENTAL ASSESSMENT;ROOFTOP GREENHOUSES;PHOSPHORUS RECOVERY;FOOD-PRODUCTION;ECONOMY;FUTURE;ENERGY;INDICATORS;IMPACTS	10.1016/j.resconrec.2020.105359
138	Cimpan, C and Iacovidou, E and Rigamonti, L and van Velzen, EUT and Cimpan, Ciprian and Iacovidou, Eleni and Rigamonti, Lucia and van Velzen, Eggo U. Thoden	2023	Keep circularity meaningful, inclusive and practical: A view into the plastics value chain	WASTE MANAGEMENT	New policies to promote the circular economy have created an urgent need for businesses and public authorities to quantify and monitor the level of circularity of materials, components and products. However, flows of ma-terials, components and products through society are inherently complex, involving intricate value chains, many stakeholders, and interests. We argue that current actions may be overly focused on superficial effects, and losing sight of true circular economy goals. Using plastic packaging as an example, the present contribution deliberates the questions, "does measuring circularity address its goals?", "does it cover new technologies and regional specificities?", and "can its goals be addressed with simple assessment approaches?". In answering these ques-tions, we argue that there is an impending risk of cementing policy and infrastructures that may not contribute to true sustainability. Furthermore, future technologies and developing regions are hardly included in the current circularity strategies. To further spark a discussion on the challenge of simplicity, we present a scorecard which can help incumbents to approximate the level of sustainable circularity of their products.	ECONOMY;INDICATORS;CHALLENGES;RESOURCES;RECOVERY;WASTE	10.1016/j.wasman.2023.04.049
139	Barros, MV and Salvador, R and Gallego-Schmid, A and Piekarski, CM and Barros, Murillo Vetroni and Salvador,	2023	Circularity measurement of external resource flows in companies: The circular flow tool	WASTE MANAGEMENT	Unlike the linear model "take-make-use-dispose", the circular economy model "grow-make-use-restore" intends to potentiate material and energy flows within a system with the premise of increasing environmental gains. Moreover, circular economy practices can be alternatives for closing loops in companies from different sectors, with material-, waste-, and energy-related initiatives towards promoting greater internal value-adding. However, the lack of consistent tools for measuring circularity of processes and companies is a gap yet to be covered. To tackle this gap, this paper's aims are: (i) to build a new tool, called Circular Flow, for generating greater internal value and competitive advantage in organizations and identify potential circular economy-related opportunities for closing loops based on external flows, (ii) to apply the tool in a case study, an organization that presents material and energy (electricity) flows and exchanges with other organizations, and (iii) to discuss the inte-gration and potential opportunities for	BUSINESS MODELS;ECONOMY;INDICATORS;IMPLEMENTATION;DESIGN	10.1016/j.wasman.2023.01.001

	Rodrigo and Gallego-Schmid, Alejandro and Piekarski, Cassiano Moro				the tool in organizations. The novel, Circular Flow, tool is based on a set of circular graph visualizations, and quantitative circularity indicators. For the graphical visualization, the software tool R (using the Circlize package) was used. The graphs aid the visualization of several interconnected pieces of information, allowing to show all quantitative flows of inputs and outputs, intuitively showing the paths (origin and destination of each flow) within the boundaries of the system under study. The quantitative in-dicators, e.g. Circularity of the organization (Circ p) and Circularity of each process (Circ o), show a circularity index ranging from 0% to 100%, which can be assessed at different levels. The criteria to select these indicators are based on quantities of inputs and outputs regarding mass and electricity. The tool has been applied in a case study of a rural property in southern Brazil, which region holds a tradition for milk and pig farming. The use of the tool showed the involvement of the rural property with its neighbors and with an agroindustrial cooperative. Keeping these flows within the system may increase environmental gains by reducing transportation, using renewable sources of energy, reducing costs, and boosting the generation of jobs and income in the region due to new market opportunities and business models.		
140	de Souza, VM and Frohling, M and Pigosso, DCA and de Souza, Vitor Miranda and Froehling, Magnus and Pigosso, Daniela C. A.	2023	A Multi-level Resource Circularity Index based in the European Union's Circular Economy Monitoring Framework	WASTE AND BIOMASS VALORIZATION	Purpose to propose two enhancements for the European Union's Circular Material Use rate (CMU): inclusion of Preparation for Reuse (PfR) flows and enhanced reproducibility across lower levels of analysis.Methods PfR flows are added to the material flow Sankey Diagram. The Local Circularity Rate (LCR) is based in the CMU and is broke down in three waste-related ratios: recovered-to-treated (RCV-to-TRT), treated-to-end-of-life and end-of-life-to-overall-material-use (EoL-to-OMU). LCR, CMU and CMU', an alternate version of CMU, are computed and compared in the macro-level for EU27 member states and in the meso-level for Germany's sixteen states. LCR is computed and broke down for regions in Belgium, The Netherlands and Greece. In the micro-level, LCR is computed for a network modelled around a Textile Sorting Centre (TSC) in Amsterdam.Results LCR showed closer average results to CMU in comparison to CMU'. Considering RCV-to-TRT and EoL-to-OMU, The Netherlands and Luxembourg are the best performing countries in the EU27. Eight countries performed worse than 0.4 in both ratios. In total, twelve German regions showed negative results, either for CMU or CMU'. Saxony-Anhalt is the most circular region in Germany, while Berlin is the less circular. The Amsterdam textiles' network features an LCR of 12%, with the TSC contributing to 63% of all textiles recovered.Conclusion The revised circular Sankey Diagram comprehensively illustrates the circularity gap. LCR's three ratios enhances in-depth analysis, allowing better prioritisation of public policies. Limitations remain in data availability and harmonisation across regional and national databases.	SUPPLY NETWORKS;METABOLISM;SYSTEMS;European Union	10.1007/s12649-023-02193-6
141	H-Hargitai, R and Somogyi, V and H-Hargitai, Reka and Somogyi, Viola	2023	Impact of water as raw material on material circularity - A case study from the Hungarian food sector	HELIYON	Measuring circularity is necessary to prove the feasibility of transforming linear technologies into circular ones. However, most of the circular economic researches consider water only as a medium. Food industry processes are excellent examples of systems that are hard to break free from linearity, albeit not impossible. This paper explores solutions to include water in circularity calculations using a Hungarian poultry processing plant as a case study. Two circular economic indicators, the questionnaire-type Circular Economy Indicator Prototype (CEIP) and the productcentric Material Circularity Indicator (MCI and MCI') and the Water Footprint were examined in detail and modified to fit the needs of assessing circularity with water included as raw material. The calculations were supported by Life Cycle Assessment (LCA). The impact on circularity and the environment were quantified by considering different reuse scenarios. As the results of CEIP show, including water reuse in the technology or recycling for irrigation could increase the indicator values from low to medium-high level of circularity. However, the level of improvement highly depends on the amount of water used. LCA highlighted the significant environmental effects of packaging (<2% of	ECONOMY INDICATORS;INDUSTRY 4.0;FOOTPRINT;CYCLE;PERFORMANCE;CONSUMPTION;BARRIERS;FUEL;Food	10.1016/j.heliyon.2023.e17587

					product mass) and the relative benefits of recycling and reuse. The MCI' values (including water as raw material) increased from 0.171 to 0.848 when water demand was reduced by 50% and 100% reused within the processes. This led to a reduction of 76% in the environmental effect. On the other hand, Water Footprint analysis showed that 99% of the water is incorporated in the product itself; therefore, technological water consumption should be treated separately from broiler breeding. The results show that a fairly linear process can be directed towards circularity. However, environmental benefits are not guaranteed with higher circularity points, and recycling may lead to unexpected results.		
142	Moller, H and Lyng, KA and Roos, E and Samsonstuen, S and Olsen, HF and Moller, Hanne and Lyng, Kari-Anne and Roos, Elin and Samsonstuen, Stine and Olsen, Hanne Fjerdingby	2023	Circularity indicators and added value to traditional LCA impact categories: example of pig production	INTERNATIONAL JOURNAL OF LIFE CYCLE ASSESSMENT	PurposeThe purpose of using circularity indicators is to show the effect of changes from linear to more circular systems. This paper contributes to highlighting the importance of methodological aspects of circularity indicators in the agricultural sector when using a life cycle thinking approach. Selected circularity indicators have been explored and compared with LCA impact categories by using them to evaluate the circularity of a livestock system.MethodsCircularity indicators were tested on a theoretical pig production system where several circularity strategies and associated mitigation actions were applied. The strategies and mitigation actions were as follows: anaerobic digestion of manure (closing resource loops), anaerobic digestion of bread waste (closing resource loops), precision fertilization (narrowing resource loops), use of cover crops in feed production (regenerating resource flows), and use of bread waste as feed (slowing resource loops). The functional unit was 1 kg pork as carcass weight, and the treatment of 1.1 kg bread waste for all impact categories and indicators. For each mitigation action, relevant circularity indicators were tested. Based on this, the functionality and suitability of these indicators were discussed.Results and discussionFour of the circularity indicators were based on nitrogen (N) or phosphorus (P) substances: N recycling index, partial N balance, consumption of fossil-P fertilizers, and emissions to water bodies (P). Even if the indicators do not capture the impact of emissions of N and P as the eutrophication impact categories, they provide a useful indication of the circularity of a system. The other three circularity indicators tested were as follows: renewable energy production, soil organic carbon, and land use ratio. The renewable energy production indicator is easy to understand and communicate and provides unique information. Soil organic carbon presents a potential for soil carbon sequestration. Land use ratio is based on the same data as land occupation but provides an assessment of whether feed production competes for the suitable area for food production by including production of human-digestible protein.ConclusionsCircularity indicators provide valuable information about the circularity of an agricultural product system. The circularity indicators and LCA impact categories can be used either separately or together, or to complement each other. The choice of indicators depends on the questions raised, i.e., goals and scope, and it is therefore important to have a number of circular indicators to choose from in order to achieve a comprehensive assessment.	NITROGEN-BALANCE;ECONOMY;MANAGEMENT;Swine	10.1007/s11367-023-02150-4
143	Oyoo, V and Riungu, JN and Dey, P and Kirimi, JG and Matheka, RM and Oyoo, Valary and Riungu, Joy Nyawira and Dey, Prasanta and	2023	Process performance evaluation of faecal matter treatment via black soldier fly	JOURNAL OF WATER SANITATION AND HYGIENE FOR DEVELOPMENT	Sustainable management of faecal matter is a prevailing global challenge. In th co-treatment of faecal matter using kitchen waste (FM:KW) to formulate five feeding substrates. About 1 kg of each feed substrate was treated utilizing 5 g of 5-day-old BSF larvae after which 100 larvae were randomly picked at 3-day intervals from each treatment to monitor the larval weight gain across the treatment process. Larval days to 50% pupation, mean pupal yield, waste reduction rate (WR), bioconversion rates (BRs), and feed conversion rates (FCRs) were monitored for the process performance. Study results showed that the substrate 1:1 attained the best measures of high WR, waste reduction index (WRI), BR, FCR, and overall pre-pupal yield within a shorter development time. Further, we modelled the BSF larval weight gain using the modified Gompertz model to assess the least time for optimal biomass conversion for animal feed processing. The BSF larvae exhibited an S-shaped growth curve and the modified Gompertz model adequately quantified	SLUDGE MANAGEMENT;HERMETIA-ILLUCENS;LARVAE;CONVERSION;SANITATION;GROWTH;Military Personnel	10.2166/washdev.2023.010

	Kirimi, James Gitonga and Matheka, Rosemary M.				the BSF larval growth performance. In the future, our methodology will pave the way for effective treatment and valorization of faecal matter from onsite sanitation facilities, manage organic municipal wastes and provide alternative animal feed and bio-fertilizer.		
144	Jia, F and Yin, SY and Chen, LJ and Chen, XW and Jia, Fu and Yin, Shiyuan and Chen, Lujie and Chen, Xiaowei	2020	The circular economy in the textile and apparel industry: A systematic literature review	JOURNAL OF CLEANER PRODUCTION	Over the past few decades, sustainable supply chain management practices have been developed to incorporate ecological issues into business by decreasing unintentional destructive effects on the environment in the process of manufacturing and purchasing. At the same time, circular economies push the boundaries of environmental sustainability by highlighting the notion of innovative goods, creating a viable relationship between ecosystems and economic growth. Through a systematic literature review, this paper identifies four themes-drivers, barriers, practices, and indicators of sustainable performance when applying a circular economy in the textile and apparel industry. We establish a conceptual model based on these four themes, which illustrates the relationship between them. We highlight challenges in circular economy implementation and provide some suggestions for managers in the textile and apparel industry. We conclude by suggesting several future research directions. (C) 2020 Elsevier Ltd. All rights reserved.	SUPPLY-CHAIN MANAGEMENT;LIFE-CYCLE ASSESSMENT;CONCEPTUAL-FRAMEWORK;REVERSE LOGISTICS;ENVIRONMENTAL IMPROVEMENT;SUSTAINABLE DEVELOPMENT;MANUFACTURING PRACTICES;SOCIAL-RESPONSIBILITY;EMERGING TECHNOLOGIES;WATER EFFICIENCY	10.1016/j.jclepro.2020.120728
145	Al-Saidi, M and Das, P and Saadaoui, I and Al-Saidi, Mohammad and Das, Probir and Saadaoui, Imen	2021	Circular Economy in Basic Supply: Framing the Approach for the Water and Food Sectors of the Gulf Cooperation Council Countries	SUSTAINABLE PRODUCTION AND CONSUMPTION	The circular economy concept can enhance sustainability through restructuring consumption and production patterns using innovative designs and business models. This core premise is highly relevant for the interlinked water and food supply sectors in arid regions, which are threatened by natural scarcity and resource overuse. This paper transfers the idea of the circular economy into the practice of the water and food sectors using the example of the region of the Gulf Cooperation Council (GCC). It develops a framework for identifying circular economy strategies and issues applicable to basic supply sectors. In analyzing the value chain and circular strategies of the water and food sectors, the circular economy idea has resulted in numerous industrial applications. The range of applications is illustrated in the key industries of wastewater and local food production. Expanding the reuse options for municipal wastewater and valorizing organic waste represent important circular economy directions for the basic supply sector of the GCC. Incorporating these ideas is positive, but a more comprehensive set of measures is needed to generate low-carbon and low-metabolism economic development in the region. In addition to the current sporadic supply-side initiatives, there is a need for non-technical circular economy strategies related to demand management and waste reduction. (C) 2021 Institution of Chemical Engineers. Published by Elsevier B.V. All rights reserved.	WASTE-WATER;ENERGY;BIODIESEL;RECOVERY;REUSE;SUSTAINABILITY;FEASIBILITY;PERSPECTIVE;BIOFERTILIZER;OPPORTUNITIES	10.1016/j.spc.2021.03.004
146	Walker, AM and Simboli, A and Vermeulen, WJV and Raggi, A and Walker, Anna M. and Simboli, Alberto and Vermeulen, Walter J. V.	2023	A dynamic capabilities perspective on implementing the Circular Transition Indicators: A case	CORPORATE SOCIAL RESPONSIBILITY AND ENVIRONMENTAL MANAGEMENT	The use of life cycle-based assessment has been defined a crucial microfoundation to implement circular business models from a dynamic capabilities perspective. Through a case study of a multi-national packaging corporation in the plastics sector, the application of an industry-developed circularity assessment, the Circular Transition Indicators (CTI), is analysed in two manufacturing locations (Italy and China). The aim is to identify how this life cycle-based assessment can amplify the company's capability to sense, seize and reconfigure its resources. Data were collected from a company placement, interviews, and sustainability reports. The CTI mainly contributed to the sensing microfoundations concerning the company's life cycle-based perspective and the use of environmental management tools. It also proved to complement existing life cycle-based approaches because it does not identify sustainability impacts, but only captures material flows. Furthermore, the results showed how the CTI implementation benefitted from existing	LIFE-CYCLE MANAGEMENT;SOCIAL SUSTAINABILITY;ECONOMY;INDUSTRY;AGENDA	10.1002/csr.2487

	and Raggi, Andrea		study of a multi-national packaging company		microfoundations, such as the strategic collaboration with knowledge partners and previously collected sustainability and process efficiency data. Finally, it was also discussed for which microfoundations the CTI results could be most useful: to improve internal resource management processes and to support external circularity pledges. This paper contributes an empirical example to connect dynamic capabilities with life cycle management literature in a circular economy context.		
147	Tsai, FM and Bui, TD and Tseng, ML and Lim, MK and Hu, JY and Tsai, Feng Ming and Bui, Tat-Dat and Tseng, Ming-Lang and Lim, Ming K. and Hu, Jiayao	2020	Municipal solid waste management in a circular economy: A data-driven bibliometric analysis	JOURNAL OF CLEANER PRODUCTION	This study aims to present a systematic data-driven bibliometric analysis on municipal solid waste management as a foundation in a circular economy. The current literature has yet to be fully developed given the complexity of the corresponding concept and knowledge. Traditional bibliometric analysis lacks the ability to screen out important keywords for future directions, and the keyword frequencies are described numerically. This study applies the entropy weight method to convert the frequencies to weights and performs regional comparisons based on a database; hence, this study contributes to the literature by providing potential future directions. The database includes 413 published articles, and 41 indicators are listed. The results are used to identify valid indicators for improvement and provide a regional state-of-the-art comparison. The top 5 indicators for future study are incineration, life cycle assessment, plastic waste, sorting solid waste, and sustainability. A bibliographic coupling analysis provides a comparison of 5 regions and reveals that Africa and North America have less studies than other regions. (C) 2020 Elsevier Ltd. All rights reserved.	LIFE-CYCLE ASSESSMENT;CORPORATE SOCIAL-RESPONSIBILITY;MULTI CRITERIA DECISION-MAKING;SUPPLY CHAIN MANAGEMENT;PLASTIC PACKAGING WASTE;PERFORMANCE INDICATORS;ENTROPY WEIGHT;ECO-INNOVATION;ASSESSMENT LCA;TO-ENERGY;Bibliometrics	10.1016/j.jclepro.2020.124132
148	Demko-Rihter, J and Sassanelli, C and Pantelic, M and Anisic, Z and Demko-Rihter, Jelena and Sassanelli, Claudio and Pantelic, Marija and Anisic, Zoran	2023	A Framework to Assess Manufacturers' Circular Economy Readiness Level in Developing Countries: An Application Case in a Serbian Packaging Company	SUSTAINABILITY	Researchers highlighted the gap between the circular economy (CE) theory and real manufacturing practices. In developing countries, the background for CE development is quite different from developed countries, where there is an established waste management structure and a robust environmental policy. In addition, a shortage of best practices, guidelines, learning experiences, frameworks, and models capable of guiding manufacturers in measuring their circular level and track a roadmap towards an improvement of their circular readiness is raised in the literature. Therefore, this research develops and proposes a framework for assessing company's CE readiness and is tailored for companies operating in developing countries. In detail, the framework investigates the two main perspectives (product and business model) that companies should consider adopting and implementing CE in their operations and business. The framework also supports companies to track an improvement roadmap through the definition of future actions and KPIs. To develop the framework, an application case with a company placed in Serbia and operating in the packaging industry has been conducted. The application of the framework unveiled that there is room for improvement in developing countries to foster CE adoption, especially in the policy context. Indeed, policy incentives and instruments of public authorities would considerably support the circular transition process in companies.	INDUSTRIAL ECOLOGY;DIMENSIONS;POLICIES;CONTEXT;Developing Countries;Developed Countries	10.3390/su15086982
149	De Oliveira Neto, G.C., Teixeira, M.M., Souza, G.L.V., Arns, V.D., Tucci, H.N.P., Amorim, M.	2022	Assessment of the Eco-Efficiency of the Circular Economy in the Recovery of Cellulose from the	POLYMERS	There is a growing demand for the adoption of cyclical processes in the fashion industry. The trends point to the reuse of cellulose from cotton fibres, obtained from industrial waste, as a substitute to the former linear processes of manufacturing, sale, use, and discarding. This study sets up to explore and assess the economic and environmental gains from the mechanical shredding of cellulose in cotton fabrics in a textile company, identifying the circularity associated with the adoption of such methods. The study resorted to a case study methodology building on interviews and observation. For the environmental estimations, the study employed the material intensity factor tool, and for the economic evaluation the study uses the return on investment. The study also offers an estimation of the circularity of the processes that were implemented. The adoption of the mechanical shredding for cotton cellulose generated economic gains of US$11,798,662.98 and	RECOVERY OF CELLULOSE; TEXTILE FIBERS; ECO-EFFICIENCY; CIRCULAR ECONOMY; TEXTILE INDUSTRY	10.3390/polym14071317

			Shredding of Textile Waste		a reduction in the environmental impact that amounts to 31,335,767,040.26 kg including the following different compartments: biotic, abiotic, water, air, and erosion. The findings suggest the existence of opportunities for the circular economy in the textile sector of about 99.69%, dissociated to the use of mechanical recycling, while limited by the consumption of electrical energy and lubricants in the recycling process, leading the way to a circular economy.		
150	Jiang, L., Bhochhibhoya, S., Slot N., de Graaf, R.	2022	Measuring product-level circularity performance: An economic value-based metric with the indicator of residual value	RESOURCES, CONSERVATION AND RECYCLING	The construction industry is becoming circular, where resources are used in a closed loop. However, no standard method is available for measuring the circularity performance of building components. The Material Circularity Indicator (MCI) is one of the most ambitious methods. However, the MCI is criticized for its reliance on mass flow and the over-optimistic assumption regarding residual value. The research thus aims to adapt the MCI by addressing these limitations by using the economic value (E) as the measurement unit and introducing a new indicator of residual value (R). A residual value calculator is also developed to quantify R. A case study approach is adopted to evaluate the effect of E and R individually. The results show that using E can award materials' contributions regarding circularity based on their relative value. Furthermore, using R can capture value change and provides different significance to materials input and output considering value difference.	CIRCULAR ECONOMY; MATERIAL CIRCULARITY INDICATOR; CIRCULARITY METRIC; ECONOMIC VALUE; RESIDUAL VALUE	10.1016/j.resconrec.2022.106541
151	Bianco, I., De Bona, A., Zanetti, M., Panepinto, D.	2023	Environmental impacts in the textile sector: A Life Cycle Assessment Case Study of a Woolen Undershirt	SUSTAINABILITY	The textile industry, known for its significant contribution to global greenhouse gas emissions, is increasingly active in exploring techniques and technologies to improve its environmental performance. The main tool to calculate environmental impacts is the Life Cycle Assessment (LCA) methodology, which is standardized and internationally recognized. Specific guidelines for the impact calculation of textile products are under development (Product Environmental Footprint Category Rules (PEFCRs) for the category of Apparel and Footwear). In this context, this study contributes to the knowledge in the textile sector through the development of a cradle-to-gate LCA of a woolen undershirt produced in Italy. This study shares robust and recent (2021) primary data for the phases of weaving, cutting, and sewing, obtained from an Italian company. Data from previous studies of the authors, as well as secondary data, are also used to complete the inventory. A further analysis is developed to include the use phase as well. The impact on climate change of one undershirt results in 11.7 kg CO_2 eq, primarily due to the farming phase of sheep, which accounts for 88% of the total emissions. The impact on climate change of energy used in the wool transformation process has a relatively low impact (11%), also thanks to the partial use of electricity produced by photovoltaic panels, while materials (e.g., chemicals) and transportation have negligible contributions. The farming phase, despite relying on secondary data, is identified as the primary contributor for most of the other indicators. Additionally, it has been found that user habits play a key role in the impact related to one wearing of the undershirt. The findings suggest that further work is necessary in the textile sector and emphasize (i) the need for guidelines, enabling the inclusion of the use phase without compromising the comparability between different LCAs of similar textile products; (ii) the need for improved traceability practices in the textile sector, to enhance inventory data collection on the raw material production (wool fibers in the case under analysis).	TEXTILE SECTOR; WEAVING; SEWING; LCA; ENVIRONMENTAL IMPACTS	10.3390/su151511666
152	Lama, V., Righi, S., Quandt, B.M.,	2022	Resource pressure of carpets: Guiding	SUSTAINABILITY	When designing a product, many decisions are made that determine the environmental impacts that the product will eventually exert on our planet. Therefore, it is paramount to have considered the environmental performance already in the design phase. In this contribution, we showcase the application of the recently developed resource pressure (RP) method to assess the environmental	CIRCULAR ECONOMY; PRODUCT DESIGN; CARPET	10.3390/su14052530

	Hischier, R., Desing, H.		their circular design		sustainability of various carpet design alternatives. This method consists of qualitative guidelines and a quantitative indicator. With the Earth's carrying capacity as a reference, the product system is evaluated in relation to its consumption of primary resources and the final generation of waste. Several scenarios are developed by following the design guidelines provided by this method. Those scenarios aim at identifying the most promising circular strategies for reducing the products' resource pressure. To assess the validity of the RP method, the results are compared to a simplified LCA study. This comparison showed a close correlation for most of the considered impact categories. It confirms that the RP method can effectively predict environmental impacts across a wide range of impact categories, reducing the amount of necessary data and simplifying the calculations. It can therefore support designers in considering the environmental effects easily, from the beginning of the design process onward. Moreover, the simplicity of this method makes it attractive for application by practitioners who are not themselves experts in environmental assessments.		
153	Shou, M., Domenech, T.	2022	Integrating LCA and blockchain technology to promote circular fashion - A case study of leather handbags	JOURNAL OF CLEANER PRODUCTION	The textile sector accounts for the fourth-highest usage of primary raw materials and water (after food, housing, and transport), the second-highest usage of land, and the fifth highest Green House Gases (GHG) emissions (EEA, 2017). While Life Cycle Assessment (LCA) has been widely used to assess the environmental impact of fashion, most studies are constrained by the lack of reliable data. Blockchain technology may enable better traceability by making origin and journey more transparent. The potential to integrate LCA and blockchain has been discussed in other sectors, but specific protocols in the fashion sector are largely missing. This study aims to address this by a) exploring the use of LCA to measure the impact reduction potential of circular strategies and b) proposing a protocol for the integration of LCA and BC to accurately assess circular practices. Using leather handbags as a case study, an LCA study is conducted comparing two circular scenarios against a baseline to quantify potential benefits from circular strategies. Subsequently, it builds a blockchain-based LCA framework to unleash circularity opportunities through enhanced traceability and data sharing. Results point to substantial environmental benefits from the circular strategies, for example, circular scenario 2 (reuse markets/second-hand leather bag) was estimated to cause between 34.8% and 53.8% lower impacts while circular scenario 1 (leather alternative) contributed to impact reduction of more than 35% of the impacts in most impact categories (10 out of 18). The results also highlight the contribution of blockchain technology to enable traceability and reliable data for identification of environmental hotspots and accurate quantification of circular potential.	CIRCULAR ECONOMY; FASHION; CIRCULAR FASHION; BLOCK CHAIN; LIFE CYCLE ASSESSMENT	10.1016/j.jclepro.2022.133557
154	Mesa, J., González-Quiroga, A., Maury, H.	2020	Developing an indicator for material selection based on durability and environmental footprint: A Circular Economy perspective	RESOURCES, CONSERVATION AND RECYCLING	The Circular Economy comprises several strategies to enhance the sustainability of products. However, most of the research in this area has focused on Recycling, Recovering and final disposal. Strategies for lifespan extension such as Reuse, Repair, Refurbish, Remanufacture and Repurpose lead to higher circularity and value throughout the lifecycle but are less studied. Here we propose a single generic indicator based on durability and environmental footprint for material selection as an early step in the design process towards extending product lifespan. The material durability indicator or MDI integrates into a single calculation chemical and mechanical durability, together with environmental impacts associated with the material. The proposed indicator incorporates parameters such as flammability resistance, resistance to ultraviolet radiation, resistance to water, resistance to organic solvents, mechanical strength, energy consumption, and carbon footprint, among others. A case study based on polymer materials selection demonstrates the usefulness of the MDI indicator, providing a holistic calculation and comparison of selection alternatives, including conventional and multicriteria approaches. The proposed indicator offers a balanced and technical measurement	MATERIAL DURABILITY; PRODUCT DESIGN; SUSTAINABILITY; DECISION MAKING; CIRCULAR ECONOMY; ECODESIGN	10.1016/j.resconrec.2020.104887

					of durability and environmental burdens in the material selection process and can potentially be applied to any engineering material.		
155	Moraga, G., Huysveld, S., De Meester, S., Dewulf, J.	2021	Development of circularity indicators based on the in-use occupation of materials	JOURNAL OF CLEANER PRODUCTION	Circularity can help to prevent depletion of the earth's limited material resources, which are vital for human's modern society. Circular economy strategies of slowing and closing loops of resources have the ultimate goal of keeping materials useful (i.e. in-use) while avoiding losses (dissipation) and hibernation of materials; therefore, appropriate indicators that can measure these aspects are necessary. We propose a measurement of the circularity of materials by quantifying their in-use occupation, that is, the maintenance of materials in a useful state in products for as long as possible, avoiding dissipation or hibernation. Specifically, two indicators were developed: in-use occupation ratio (UOR) and final retention in society (FRS). These indicators were applied in two case studies (materials in a laptop and wood products) with three scenarios each (linear, reuse, and recycling). The reuse scenarios generally presented a higher UOR (41–48% for laptop materials and 53% for wood) compared to recycling scenarios (29–45% for laptop materials and 52% for wood). Only two scenarios of wood products resulted in retaining materials for the next generation (FRS > 0%). We argue that the differentiation between supply, in-use, and hibernation phases is essential for a circular economy. The occupation of materials is shown in charts to facilitate understanding by non-experts and can provide a scientific basis for policies supporting technologies or products with increased in-use occupation and retention of materials.	CIRCULAR ECONOMY; CIRCULARITY; INDICATOR; CASCADING; LIFE CYCLE THINKING; RAW MATERIAL	10.1016/j.jclepro.2020.123889
156	Lavallais, C., Dunn, J.	2023	Developing product level indicators to advance the nitrogen circular economy	RESOURCES, CONSERVATION AND RECYCLING	Increasingly, circularity indicators for material, energy, and water systems guide circular economy design. While indicators for products made from recycled carbon-based materials are somewhat common, peer indicators for waste nitrogen-derived products are limited. It is important, however, to develop such indicators to guide emerging technologies that transform waste nitrogen into products. In this study, we summarize the nitrogen circularity indicator literature, emphasizing the agricultural and wastewater sectors. Next, we use the Material Circularity Indicator (MCI) developed by the Ellen MacArthur Foundation, to quantify the circularity of products made from waste nitrogen in swine manure. We considered four test cases using different technologies to recover nitrogen from the manure. Our analysis indicates that technologies that seem to increase circularity on the surface may not yield a substantial increase in MCI results. Finally, we discuss the strengths and weaknesses of using the MCI for product-level analysis and further developments.	CIRCULAR ECONOMY, NITROGEN; INDICATORS	10.1016/j.resconrec.2023.107167
157	Kulakovskaya, A., Wiprächtiger, M., Knoeri, C., Bening, C.R.	2023	Integrated environmental-economic circular economy assessment: Application to the case of expanded polystyrene	RESOURCES, CONSERVATION AND RECYCLING	Circular Economy (CE), despite its great potential, is often challenged for not being sustainable from an environmental, economic and social perspective, or at least not in all dimensions simultaneously. Therefore, assessments that integrate different sustainability dimensions are necessary to facilitate CE implementation, particularly before entire value chains are reconfigured or incentivized to do so. However, integrated CE assessment methods remain scarce, especially at a value-chain level. We aim to bridge this gap by suggesting an approach that evaluates and integrates the environmental and economic impacts of implementing CE at the value-chain level. The approach is based on material flow analysis, life-cycle assessment, life-cycle costing, and scenario development. The application of the approach to the expanded polystyrene (EPS) value chain revealed that EPS recycling can be environmentally and economically beneficial in the long term. The approach was developed to support political and industrial decision-makers seeking to implement a sustainable CE.	CIRCULAR ECONOMY; LIFE-CYCLE THINKING; VALUE CHAIN; ENVIRONMENTAL ASSESSMENT; ECONOMIC ASSESSMENT	10.1016/j.resconrec.2023.107069
158	Griffiths, P., & Cayzer, S.	2016	Design of indicators for measurin	SMART INNOVATION, SYSTEMS AND	This paper explores measurement of product performance with respect to circular economy principles. Potential indicators are assessed, with special attention given to questions such as: the variables that should be measured; how these variables should be assessed; and in which format they should be presented. The resulting	CIRCULAR ECONOMY; METRICS	10.1007/978-3-319-32098-4_27

			g product performance in the Circular Economy	TECHNOLOGIES	considerations are used to develop a prototype whose design is informed through feedback from Circular Economy experts. The prototype uses a points-based questionnaire which converges into a simple final result with minimum and maximum limits. The selected approach is critically appraised, and its utility for decision-making discussed. The strengths include: ease of use; simplicity; speed; and an effective metaphor for the diffusion of circular economy principles. The limitations include: the opaque and potentially misleading nature of a single metric; superficial engagement with decision making; and the reliance on context specific assumptions. Future developments could include refining the approach to encourage deeper reflection, and generalization of the approach to different industry sectors or sustainability frameworks.		
159	Pauliuk, S.	2018	Critical appraisal of the circular economy standard BS8001: 2017 and a dashboard of quantitative system indicators for its implementation in organizations	RESOURCES, CONSERVATION AND RECYCLING	So far, organizations had no authoritative guidance on circular economy (CE) principles, strategies, implementation, and monitoring. Consequentially, the British Standards Institution recently launched a new standard "BS 8001:2017 – Framework for implementing the principles of the circular economy in organizations". BS 8001:2017 tries to reconcile the far-reaching ambitions of the CE with established business routines. The standard contains a comprehensive list of CE terms and definitions, a set of general CE principles, a flexible management framework for implementing CE strategies in organizations, and a detailed description of economic, environmental, design, marketing, and legal issues related to the CE. The guidance on monitoring CE strategy implementation, however, remains vague. The standard stipulates that organizations are solely responsible for choosing appropriate CE indicators. Its authors do not elaborate on the links between CE strategy monitoring and the relevant and already standardized quantitative tools life cycle assessment (LCA) and material flow cost accounting (MFCA). Here a general system definition for deriving CE indicators is proposed. Based on the system definition and the indicator literature a dashboard of new and established quantitative indicators for CE strategy assessment in organizations is then compiled. The dashboard indicators are mostly based on material flow analysis (MFA), MFCA, and LCA. Steel cycle data are used to illustrate potential core CE indicators, notably, the residence time of a material in the techno-sphere (currently 250–300 years for steel). Moreover, organizations need to monitor their contribution to in-use-stock growth, a central driver of resource depletion and hindrance to closing material cycles.	CIRCULAR ECONOMY; CIRCULARITY INDICATOR; BS 8001; 3R; MATERIAL FLOW ANALYSIS; LIFE CYCLE ASSESSMENT	10.1016/j.resconrec.2017.10.019
160	Poponi, S., Arcese, G., Pacchera, F., & Martucci, O.	2022	Evaluating the transition to the circular economy in the agri-food sector: Selection of indicators	RESOURCES, CONSERVATION AND RECYCLING	The agri-food sector is one of the key sectors where the action is needed to ensure the transition to a more sustainable development model in line with the principles of the circular economy (CE). The use of indicators to monitor progress and areas for action is a key element in the shift of companies, regions, and countries toward a circular model. This study aims to create a dashboard that can be used at various spatial levels to guide the agri-food sector toward a CE and sustainable development. Starting with the relevant literature, we identified 102 indicators classified according to three areas of sustainability (environmental, economic and social) and spatial dimensions (macro-meso-micro) within 8 scopes. The dashboard provides a toolbox for directing decision-making processes and strategies through the targeted use of indicators with respect to the context in which the CE is applied. In addition, the dashboard allows us to highlight missing aspects related to (1) new indicators not covered by the tool; (2) new scopes not yet explored in the literature; and (3) the need to adopt cross-sectional indicators. For this last aspect, the analysis revealed only 17 such indicators. A future step is to define the most suitable configurations among the indicators in which CE is generated, starting from the test of the indicators at the micro level to validate their applicability and consider the impacts they may have at the macro or meso levels.	CIRCULAR ECONOMY; AGRI-FOOD; SUPPLY CHAIN; CLOSED-LOOP; MULTI-LEVEL INDICATORS	10.1016/j.resconrec.2021.105916
161	Velasco-Muñoz, J., Mendoza, J.,	2021	Circular economy impleme	RESOURCES, CONSERVATI	In the current context of resource scarcity, global climate change, environmental degradation, and increasing food demand, the circular economy (CE) represents a promising strategy for supporting sustainable, restorative, and regenerative	BIOECONOMY; CLOSING RESOURCE LOOPS; NARROWING RESOURCE	10.1016/j.resconrec.2021.105618

	Aznar-Sánchez, J., & Gallego-Schmid, A.		ntation in the agricultural sector: Definition, strategies and indicators	ON AND RECYCLING	agriculture. A review of the literature on CE confirms the initial hypothesis that the theoretical CE framework has not yet been adapted to the field of agriculture. Therefore, this paper overcomes this gap in two ways: i) by adjusting the general CE framework to the agricultural sector's specificities, and ii) by analyzing the scope of the indicators available for measuring agricultural production systems' circularity performance in supporting decision-making processes. Accordingly, the different elements in the theoretical CE framework are adapted to agricultural production systems. One major contribution of this paper is the definition of CE applied to agriculture. In addition, the principles of CE are adapted to the field, and CE strategies for agricultural activity are defined. Forty-one circularity indicators for application in agricultural systems were also comprehensively assessed to determine their strengths and weaknesses. Building on the key findings, future research paths and changes at the institutional and normative levels are proposed to facilitate CE implementation in agricultural production systems. For example, internationally recognized standards and adequate units of measurement must be defined, to develop meaningful studies and determine agricultural activities' circularity performance.	LOOPS; SLOWING RESOURCE LOOPS; REGENERATIVE AGRICULTURE; SUSTAINABILITY	
162	Hessel, V., Escribà-Gelonch, M., Bricout, J., Tran, N. N., Anastasopoulou, A., Ferlin, F., Valentini, F., Lanari, D., & Vaccaro, L.	2021	Quantitative Sustainability Assessment of Flow Chemistry–From Simple Metrics to Holistic Assessment	ACS Sustainable Chemistry & Engineering	Flow chemistry has changed chemical process designs toward process intensification and is generally considered as green methodology. In this connection, this perspective provides a more critical and holistic view about the sustainability of flow chemistry by introducing both simple and complex holistic tools for environmental quantitative assessment on sustainability and providing examples of how they were used for flow chemistry. The latter also shows a critical assessment of what flow chemistry can add to make chemical processes more sustainable. With the increasing complexity of assessment, green chemistry metrics, life cycle assessment methodology, and circular transition indicators are discussed. In this way, the sustainability of flow chemistry is assessed first on the level of a reaction only and then moving to a process level and beyond. Flow chemists are very aware of the principles of green chemistry and their simple metrics. Yet, they hardly use life cycle assessment, and quantitative circularity analysis has not been made. When those assessments are used, it is usually done by researchers with an ecology background. This perspective aims to make flow chemists aware of the opportunities that complex environmental assessment can provide and that protecting our planet requires a holistic sustainability consideration. The perspective critically states what each of the three types of assessments can do and what their limitations are.	FLOW CHEMISTRY; GREEN METRICS; LIFE CYCLE ASSESSMENT; CIRCULAR ECONOMY; SUSTAINABILITY ASSESSMENT	10.1021/acssuschemeng.1c02501

Table S2. Characterization of product-level bio-based circularity indicators based on attributes.

Nr.	Indicators	Sector				Aspects included										Well-established frameworks		Type of value	
		General	Fertilizer	Packaging	Textiles	Recycled/reused input	Efficiency	Product lifetime	End-of-life processes	Recyclability	Energy	Environmental impact	Entropy	Economic input	Benchmark against linear	LCA-based	MCI-based	Relative	Absolute
Systematic Literature Review																			
1	Additives impact on sustainability of organic recycling		✓	✓					✓			✓						✓	
2	Atom Economy	✓					✓											✓	
3	Bio-based Fertilizers (BBFs) indicators		✓												✓			✓	
4	Biodegradable content	✓																✓	
5	Carbon Circularity Indicator		✓			✓	✓											✓	
6	Carbon Circularity Rate			✓		✓												✓	
7	Circo-economic indicator	✓												✓			✓	✓	
8	Circular Economy Index	✓								✓				✓				✓	
9	Circular Economy Package			✓		✓				✓	✓							✓	

Nr.	Indicators	Sector				Aspects included										Well-established frameworks		Type of value	
		General	Fertilizer	Packaging	Textiles	Recycled/reused input	Efficiency	Product lifetime	End-of-life processes	Recyclability	Energy	Environmental impact	Entropy	Economic input	Benchmark against linear	LCA-based	MCI-based	Relative	Absolute
10	Circular Economy Performance Indicator	✓							✓	✓	✓	✓				✓		✓	
11	Circular Index – CirculAbility model	✓				✓		✓	✓	✓	✓							✓	
12	Circularity indicators for designing and selecting food packaging			✓		✓		✓	✓	✓	✓							✓	
13	Circular Material Use Rate	✓				✓												✓	
14	Circular Process Energy Intensity	✓					✓		✓		✓							✓	
15	Circularity Index (Cullen, 2017)	✓					✓				✓							✓	
16	Circularity Index (Y. Zhang et al., 2024)	✓				✓				✓								✓	
17	Circularity Index for Textiles				✓							✓		✓	✓			✓	

Nr.	Indicators	Sector				Aspects included										Well-established frameworks		Type of value	
		General	Fertilizer	Packaging	Textiles	Recycled/reused input	Efficiency	Product lifetime	End-of-life processes	Recyclability	Energy	Environmental impact	Entropy	Economic input	Benchmark against linear	LCA-based	MCI-based	Relative	Absolute
18	Circularity Indicator for Resource Recovery at a WWTP		✓			✓	✓				✓							✓	
19	Circularity Indicator of Component i		✓			✓	✓											✓	
20	Circularity Indicators of N and P		✓				✓											✓	
21	Collection Rate			✓			✓											✓	
22	Cyclical Use Rate Indicator	✓				✓												✓	
23	Ecological Sustainability Index				✓				✓	✓		✓				✓		✓	
24	EcoStrategic Index		✓										✓	✓				✓	
25	Emergy	✓									✓								✓
26	Environmental Factor	✓					✓					✓						✓	
27	Green Aspiration Level	✓					✓					✓							✓

Nr.	Indicators	Sector				Aspects included										Well-established frameworks		Type of value	
		General	Fertilizer	Packaging	Textiles	Recycled/reused input	Efficiency	Product lifetime	End-of-life processes	Recyclability	Energy	Environmental impact	Entropy	Economic input	Benchmark against linear	LCA-based	MCI-based	Relative	Absolute
28	Green Protein Food Index		✓												✓	✓		✓	
29	Indicator of Circular Economy for Biofertilizer		✓			✓												✓	
30	In-use occupation of materials	✓						✓											✓
31	Joint Entropy			✓									✓					✓	
32	Levelized Cost of Waste		✓		✓									✓					✓
33	Littering Potential			✓					✓									✓	
34	Longevity Factor	✓						✓							✓				✓
35	Mass Intensity Total				✓														✓
36	Material Circularity Indicator	✓				✓		✓	✓	✓					✓		✓	✓	
37	Material Durability Indicator			✓				✓								✓			✓

Nr.	Indicators	Sector				Aspects included										Well-established frameworks		Type of value	
		General	Fertilizer	Packaging	Textiles	Recycled/reused input	Efficiency	Product lifetime	End-of-life processes	Recyclability	Energy	Environmental impact	Entropy	Economic input	Benchmark against linear	LCA-based	MCI-based	Relative	Absolute
38	Material Reutilization Score	✓				✓				✓								✓	
39	Maximum Achievable Circularity	✓																✓	
40	MCI based on economic and residual value	✓												✓			✓	✓	
41	MCI coupled with LCA	✓														✓	✓	✓	
42	Modified MCI		✓			✓	✓	✓	✓	✓				✓	✓		✓	✓	
43	Nitrogen Use Efficiency		✓				✓											✓	
44	Nutrient Recycling Index		✓			✓												✓	
45	Nutrient Removal Efficiency Indicator		✓			✓												✓	
46	Nutrient Slow-Release Indicator		✓					✓										✓	

Nr.	Indicators	Sector				Aspects included										Well-established frameworks		Type of value	
		General	Fertilizer	Packaging	Textiles	Recycled/reused input	Efficiency	Product lifetime	End-of-life processes	Recyclability	Energy	Environmental impact	Entropy	Economic input	Benchmark against linear	LCA-based	MCI-based	Relative	Absolute
47	Organic Recycling Efficiency		✓	✓		✓	✓		✓									✓	
48	Packaging Index			✓						✓		✓				✓		✓	
49	Percentage Biodegradation		✓						✓									✓	
50	Percentage Circularity	✓				✓				✓								✓	
51	Plastic Circularity Index			✓				✓	✓								✓	✓	
52	Process Excellence Index	✓					✓											✓	
53	Process Improvement	✓					✓					✓						✓	
54	Process Mass Intensity	✓					✓											✓	
55	Process Yield / Net Recovery			✓		✓	✓											✓	
56	Product Circularity Indicator	✓				✓			✓						✓		✓	✓	
57	Product Circularity	✓				✓				✓								✓	

Nr.	Indicators	Sector				Aspects included										Well-established frameworks		Type of value	
		General	Fertilizer	Packaging	Textiles	Recycled/reused input	Efficiency	Product lifetime	End-of-life processes	Recyclability	Energy	Environmental impact	Entropy	Economic input	Benchmark against linear	LCA-based	MCI-based	Relative	Absolute
	Metric (UL 3600)																		
58	Product Index	✓							✓	✓								✓	
59	Product Sustainability Index				✓			✓				✓				✓		✓	
60	Product-level Circularity	✓				✓								✓				✓	
61	Product-level Circularity Metric	✓												✓				✓	
62	Quality Indicator			✓			✓											✓	
63	Quality Model for Recycled Plastics			✓					✓	✓								✓	
64	Quality of Recycling Framework	✓						✓	✓			✓		✓					✓
65	Recycled Input Rate			✓		✓												✓	
66	Recycled Potential Performance			✓		✓	✓											✓	
67	Recycling			✓			✓						✓					✓	

Nr.	Indicators	Sector				Aspects included										Well-established frameworks		Type of value	
		General	Fertilizer	Packaging	Textiles	Recycled/reused input	Efficiency	Product lifetime	End-of-life processes	Recyclability	Energy	Environmental impact	Entropy	Economic input	Benchmark against linear	LCA-based	MCI-based	Relative	Absolute
	Effectiveness																		
68	Recycling Rate			✓		✓	✓											✓	
69	Regenerative Capacity Index	✓										✓						✓	
70	Relative Antibiotic-to-Phosphorus Ratio		✓															✓	
71	Relative Green Process Improvement	✓					✓					✓						✓	
72	Relative Process Complexity Improvement	✓																✓	
73	Relative Process Greenness	✓					✓					✓						✓	
74	Renewable Energy Use		✓	✓			✓				✓							✓	
75	ResCom Circularity Calculator	✓				✓		✓	✓	✓				✓				✓	

Nr.	Indicators	Sector				Aspects included										Well-established frameworks		Type of value	
		General	Fertilizer	Packaging	Textiles	Recycled/reused input	Efficiency	Product lifetime	End-of-life processes	Recyclability	Energy	Environmental impact	Entropy	Economic input	Benchmark against linear	LCA-based	MCI-based	Relative	Absolute
76	Residuals, solid waste		✓				✓		✓									✓	
77	Resource Flow Indicators		✓			✓	✓				✓			✓				✓	
78	Resource Pressure				✓		✓	✓				✓						✓	
79	Sorting Efficiency			✓		✓	✓											✓	
80	Sorting Rate			✓			✓											✓	
81	Statistical Entropy			✓			✓						✓						✓
82	Textile Sustainability Index				✓							✓		✓				✓	
83	Total Energy Consumption Efficiency		✓	✓			✓				✓							✓	
84	Total Water Consumption Efficiency		✓	✓			✓					✓						✓	
85	Value-based Resource Efficiency Indicator	✓					✓							✓				✓	

Nr.	Indicators	Sector				Aspects included										Well-established frameworks		Type of value	
		General	Fertilizer	Packaging	Textiles	Recycled/reused input	Efficiency	Product lifetime	End-of-life processes	Recyclability	Energy	Environmental impact	Entropy	Economic input	Benchmark against linear	LCA-based	MCI-based	Relative	Absolute
86	Volume-Time-Output	✓					✓												✓
87	Waste Index	✓							✓	✓								✓	
88	Yarn Knittability				✓					✓								✓	
Grey literature																			
89	% Critical material	✓																✓	
90	% Material circularity	✓				✓	✓		✓	✓								✓	
91	% Recovery type	✓							✓	✓								✓	
92	% Renewable energy	✓									✓							✓	
93	% Water circularity	✓					✓					✓						✓	
94	Actual lifetime	✓						✓							✓			✓	
95	Average lifetime of product or material relative to industry average	✓						✓							✓			✓	
96	Average per cent of energy consumed that	✓									✓							✓	

Nr.	Indicators	Sector				Aspects included										Well-established frameworks		Type of value	
		General	Fertilizer	Packaging	Textiles	Recycled/reused input	Efficiency	Product lifetime	End-of-life processes	Recyclability	Energy	Environmental impact	Entropy	Economic input	Benchmark against linear	LCA-based	MCI-based	Relative	Absolute
	is renewable energy																		
97	Average recycled content of an inflow	✓				✓												✓	
98	Average renewable content of an inflow	✓																✓	
99	Average reuse content of an inflow	✓				✓												✓	
100	Bio-based carbon content	✓																✓	
101	Bio-based content	✓																✓	
102	Circular material productivity	✓					✓							✓				✓	
103	CTI revenue	✓				✓				✓				✓				✓	
104	Energy intensity	✓					✓				✓							✓	
105	GHG impact	✓										✓							✓
106	Material productivity	✓					✓							✓				✓	
107	Nature impact	✓										✓							✓

Nr.	Indicators	Sector				Aspects included										Well-established frameworks		Type of value	
		General	Fertilizer	Packaging	Textiles	Recycled/reused input	Efficiency	Product lifetime	End-of-life processes	Recyclability	Energy	Environmental impact	Entropy	Economic input	Benchmark against linear	LCA-based	MCI-based	Relative	Absolute
108	Onsite water circulation	✓					✓					✓						✓	
109	Per cent actual recirculation of outflow in the biological cycle	✓							✓	✓								✓	
110	Per cent actual recycled material derived from outflow	✓							✓	✓								✓	
111	Per cent actual reused products and components derived from outflow	✓							✓	✓								✓	
112	Per cent designed recyclability rate of the outflow	✓							✓	✓								✓	
113	Per cent designed reusability of the	✓							✓	✓								✓	

Nr.	Indicators	Sector				Aspects included										Well-established frameworks		Type of value	
		General	Fertilizer	Packaging	Textiles	Recycled/reused input	Efficiency	Product lifetime	End-of-life processes	Recyclability	Energy	Environmental impact	Entropy	Economic input	Benchmark against linear	LCA-based	MCI-based	Relative	Absolute
	outflow																		
114	Per cent energy recovered from residual, non-renewable and non-recoverable resource outflows	✓									✓							✓	
115	Per cent of nutrient-extracted water discharged	✓							✓	✓		✓						✓	
116	Per cent water discharged in accordance with quality requirements	✓										✓						✓	
117	Per cent water withdrawal from inflow circular sources	✓				✓												✓	
118	Percentage of	✓					✓											✓	

Nr.	Indicators	Sector				Aspects included										Well-established frameworks		Type of value	
		General	Fertilizer	Packaging	Textiles	Recycled/reused input	Efficiency	Product lifetime	End-of-life processes	Recyclability	Energy	Environmental impact	Entropy	Economic input	Benchmark against linear	LCA-based	MCI-based	Relative	Absolute
	extracted surplus materials																		
119	Ratio (on-site or internal) water reuse or recirculation	✓										✓						✓	
120	Resource intensity index	✓					✓							✓				✓	
121	Resource productivity	✓												✓				✓	
122	Value per mass	✓					✓							✓				✓	
123	Water intensity	✓					✓					✓						✓	