



Automobile Sector Closing the Loop through Life Cycle Assessment

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ABSTRACT

The automobile sector is growing exponentially with robust demand due to higher disposable income and technological advancement. Responsible production and consumption is one of the SDGs making it imperative for the manufacturers to adopt ecological practices for mitigating risk and improving sustainability. Circular Economy is a philosophy which can be applied at micro, meso and macro levels but focuses more on resource efficiency. LCA on the other hand is a science based methodology considering all the stages on a products' life cycle thus more comprehensive though it is just an analytical tool. The study seeks to find the extent to which Indian automobile industry undertakes LCA and nexus between LCA and CE. BSE Auto Index constituent companies have been considered for the study as they represent the sector with PAN India presence and serve many international markets. Content analysis of Business Responsibility and Sustainability Reports 2023-24 was undertaken. Results support the argument that LCA is a tool enabling transition to Circular economy which ultimately leads to sustainability.

Introduction:



Circular Economy is a regenerative system where products and materials are reused, refurbished, or recycled following the waste hierarchy, rather than being incinerated or discarded.(Hansen et al., n.d.) As a result, less virgin material is needed, reducing the demand for raw materials, minimizing raw material depletion, lowering emissions, and easing pressure on vulnerable ecosystems.

LCA is a science based methodology, an analytical tool that identifies and minimises environmental impact of each stage of a product's life cycle and comprises of designing and managing a product that is ecologically sustainable.(Ha et al., 1998) Environmental footprints of four product life cycle stages i.e. material, manufacturing, usage and end of life are assessed using LCA. Based on the scope of the assessment it may be classified into Cradle to gate consisting of Material and manufacturing process and Cradle to Grave consisting of all the stages.(Zabalza Bribián et al., 2009)

Customers' demands for independence, reduced travel time, comfort, reliability, privacy, and personal mobility are driving forces behind automobile industry's boom. But it is causing environmental degradation as it is one of the most resource-intensive, heavily polluting, yet highly influential consumer products in today's industrial society.(Ha et al., 1998)

There is growing consumption in the automobile sector due to increased population, higher disposable income, and continuously improving technology which is driving down the prices. (Patel & Singh, 2022)Growing consumption increases the waste generation resulting in deterioration of the environment and may become critical if not addressed immediately.

CE principles and strategies aim to reduce economic and environmental impact yielding better results to all stakeholders and society at large. (Patel & Singh, 2022) Regulatory framework and adoption of Circular economy by original equipment manufacturers and Automobile manufacturers can bring about sustainability despite growing consumption.(Patel & Singh, 2022)

Automobile consists of several component parts which are manufactured outside the automobile manufacturing facilities. Automobile manufacturing and assembly is a complex process involving a network of original equipment manufacturers and suppliers which poses a challenge in conducting LCA making it time-consuming and expensive.(Ha et al., 1998)

Resource efficiency and circularity have a very high impact on business success and high importance to stakeholders as shown in figure 1.

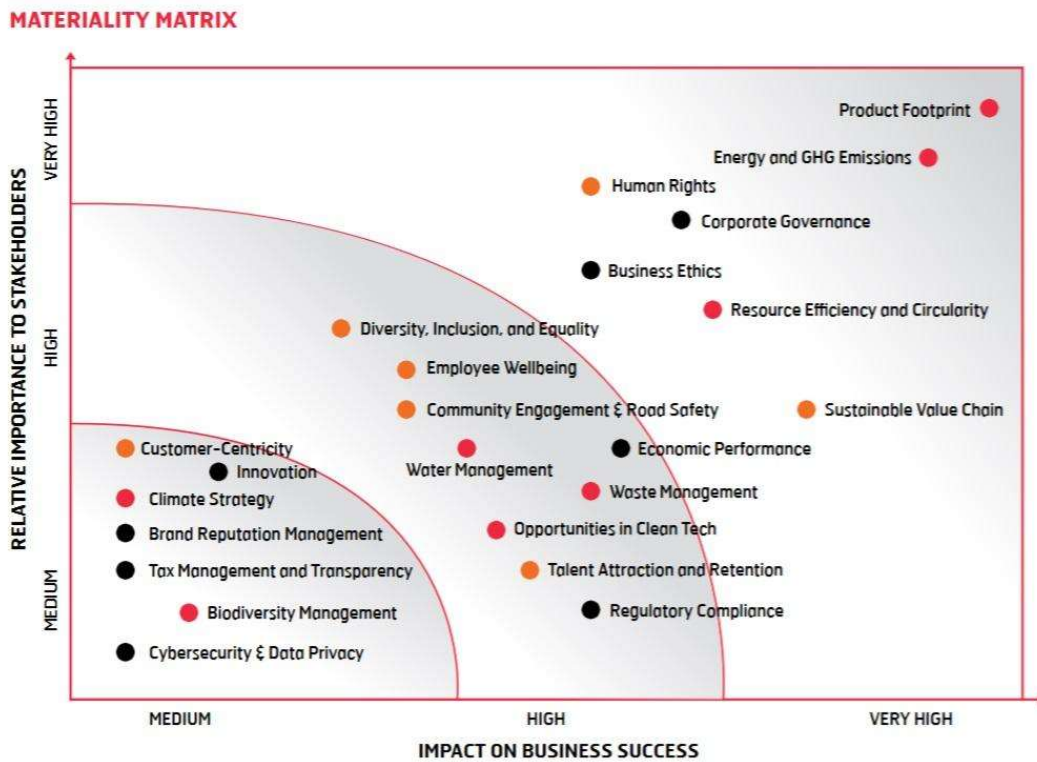


Figure 1: Impact of different variables on business success and their relative importance to stakeholders.

Source: Eicher Motors Integrated Annual Report 2023-24

Theoretical Framework:

Previous studies highlight that Closing the Loop need not always yield favorable environmental impact.(Geyer et al., 2016; Humbert et al., 2009; Laner & Rechberger, 2007) However Initiatives concentrate on advancing towards a circular economy (CE) without relying on life cycle assessment (LCA) to assess actions and goals. Circular economy is a philosophy covering global economy and society while LCA is a tool as shown in figure 2.(Haupt & Zschokke, 2017)

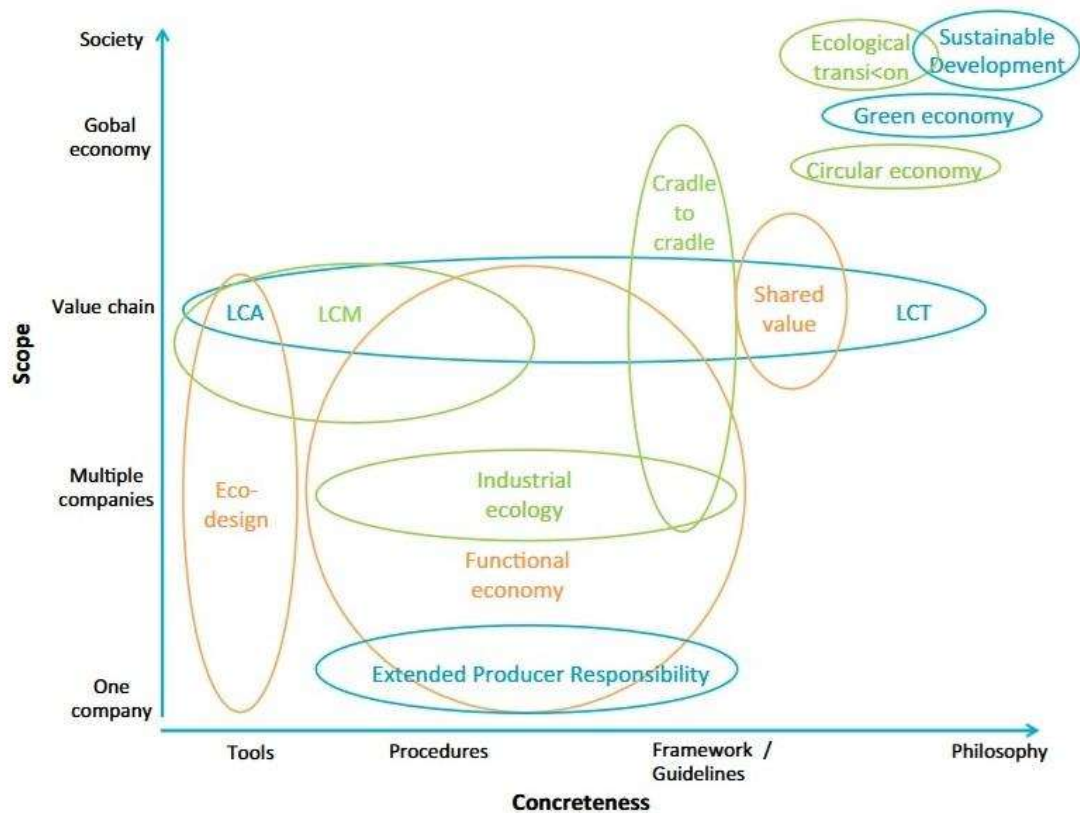


Figure 2: Map of tools and concepts based on their scope and concreteness.

Source: CIRAIG_Circular_Economy_Literature_Review_Oct2015

The viability of a closed-loop economy remains uncertain. In principle, there is general consensus that tools like LCA and other assessment methods should be employed to evaluate potential circular economy solutions. This would help ensure that the efforts and benefits of both new product designs and enhanced recycling are balanced positively. (Haupt & Zschokke, 2017)

The scope and coverage of LCA studies are often restricted, making them insufficient to fully support a circular economy viewpoint. (Schwarz et al., 2021)

LCA and related methodologies make decision making on CE strategies easier. LCA covers a whole range of impact categories whereas CE focuses on resource use and materiality. (Peña et al., 2021)

The adoption of life cycle assessment improves the thoroughness and transparency of implementing a circular economy. Dynamic LCA which includes time factor can improve applicability of LCA in CE (Lei et al., 2021)



During use phase contamination enters material cycle which must be separated and directed to final sinks. All circular options are not environmental friendly. (Haupt & Zschokke, 2017) circularity indicators provide partial view of environmental performances but circularity indicators are easier to communicate which impacts reputation among stakeholders thus increasing access to funding. (Rigamonti & Mancini, 2021)

The research questions that arise on after literature survey are: A) To what extent LCA has been conducted by the Automobile manufacturers? B) How many manufacturers mention circular economy related terminologies in the Material issues identified? C) What are the approaches adopted to mitigate the risk perceived by the companies concerning resource efficiency and circularity? D) What is the nexus between CE and LCA?

Methodology:

SEBI has mandated a Business Responsibility and Sustainability Report (BRSR) for listed entities. Introduced on 23rd August 2004, BSE Auto index tracks 18 companies from the BSE 500(Index Universe) that belong to the transportation equipment sector, as per the BSE industry classification. All the constituent companies have PAN India presence and serve international Markets too. Business responsibility and sustainability report 2023-24 of these 18 companies were considered for the content analysis. The search strings used to access specific content were “LCA” or “Life Cycle Assessment” and “Material Issues Identified” and “Circular Economy” or “Circularity”. The resulting highlighted texts were transferred to MS Excel for content analysis. It is a descriptive research work that seeks to describe the nexus between LCA and CE and the approaches adopted by the companies to mitigate risk concerning material issues identified. The overview of the chosen companies has been detailed in table 1.

Table 1: Details of 18 Companies in Auto Sector chosen for the study.

FULL NAME	YEAR OF INCORPORATION	Paid up Capital	NO. OF PLANTS		Markets Served	
			National	International	National	International
Tata Motors Limited	1945	₹767 crore	7	0	Pan India	125
Bajaj Auto Ltd.	2007	Rs.279.18 crore	5	0	Pan India	80 Countries



Mahindra & Mahindra Limited	1945	Rs. 621.76 Cr.	38	0	28+6	67
Maruti Suzuki India Limited	1981	Rs. 1,572 million	2	0	Pan india	Export to 125 countries
Exide Industries Limited	1947	Rs. 85 Crores	11	0	37	63
Hero MotoCorp Limited	19-01-1984	Rs. 39,98,43,482	8	2	32	48
Ashok Leyland Limited	1948	INR 293.63 Crores	9	0	28	47
Bharat Forge Limited	1961	Rs. 931.27 million	5	0	15	27
SAMVARDHANA MOTHERSON INTERNATIONAL LIMITED	1986	Rs. 6,776,421,366	79	205	28+8	Over 58
TVS Motor Company Limited	10-06-1992	Rs.47,50,87,114	3	0	22	91 Countries
Uno Minda Limited (formerly known as 'Minda Industries limited')	16-Sep-92	Rs.1,14,81,89,150	59 (including warehouses)	0	All States & UT in India	13
Eicher Motors Ltd.	October 14, 1982	Rs. 27.38 Crores	3	5	All Over India	65 Countries



Apollo Tyres Ltd.	28-09-1972	RS. 635,100,946	5	2	Pan India	100+Countries
MRF Limited	05-11-1960	Rs.42411430	10	0	28+8	75+
Bosch Limited	November 12, 1951	Rs.294,936,400	7	0	35	39
Sundram Fasteners Limited (SFL)	1962	Rs. 21.01 crores	18	2	28+8	35
Balkrishna Industries Limited	1961	Rs.3,866 Lakhs	9	0	PAN India presence	130+
Tube Investments of India Limited ("TII")	2008	₹19.34 Crores	25	0	30	47(Exports to countries in Asia, Europe and USA)

Results and discussions:

LCA conducted by Automobile Industry:

Nine of the chosen eighteen companies have undertaken LCA. Only four companies have conducted it on the products contributing 20% and above to the total turnover. The boundary for which the LCA was conducted is cradle-to-grave for 7 companies and cradle-to-gate for 2 companies. LCA is conducted by an independent external agency for seven of the 9 companies that have undertaken LCA. Results are mostly not communicated in the public domain except for two companies namely Hero Motor Corp and Eicher Motors.

Table 2: LCA undertaken by Automobile industry:

Companies which conducted LCA	% of total turnover contributed	Boundary for which the Life Cycle Perspective	Whether conducted by independent external	Results communicated in public domain (Yes/
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		/ Assessment was conducted	agency (Yes/No)	No) If yes, provide the web-link
EXIDEIND	2.36%	Cradle-to-Grave	Yes	No
APOLLOTYRE	4.39%	Cradle-to-Grave 4.36% Gate to Gate 0.03%	Yes	No
BOSCHLTD	7.03%	Cradle-to-Grave	Yes	No
M&M	7.10%	Cradle-to-Grave	Yes	No
HEROMOTOCO	20.40%	Cradle-to-Grave	Yes	Yes
TATAMOTORS	23%	Cradle to Gate	No	No
EICHERMOT	39%	Cradle-to-Grave	Yes	Yes
MOTHERSON	90%	Cradle to Gate	Yes	No
TVSMOTOR	Conducted on a single product- Revenue yet to be realised	Cradle-to-Grave	No	NA

LCA was not conducted by UnoMinda Ltd., MRF, Sundaram Fastners. Whereas Balakrishna Industries Ltd. and Bharatforge Ltd. intend to conduct LCA in the upcoming years. TII India, Ashok Leyland and Maruthi Suzuki have initiated LCA and planning to undertake it for more products in future. The excerpts from the BRSR have been shown in Table 3.

Table 3: LCA at nascent stage.

Name of the company	LCA Activity
TIINDIA	appointed a consultant and initiated the process



ASHOKLEY	Conducted a simplified LCA covering a few of its products- Cradle to Grave, intending to do it for all products in the future
MARUTI	Select Models, Pilot projects, internal Capacity building and learning, collaboration with 3rd parties
BAJAJ-AUTO	Conducted but no details of % of turnover and boundary are given in BRSR

Seventeen companies have explicitly mentioned CE terminologies in the Material issues identified. 9 companies identify resource efficiency, Circular economy, and waste management as opportunity while 5 companies consider it risk. 3 companies consider it as an opportunity and risk.

Table 4: Companies that have explicitly mentioned terminologies about circular economy in the material issues

	Material issue identified	Indicate whether risk or opportunity (R/O)
TATAMOTORS	Circularity	Opportunity
BAJAJ-AUTO	Waste Management	Risk
M&M	Waste to Wealth	Opportunity
MARUTI	Effective and efficient use of natural resources	Opportunity
EXIDEIND	Waste Management	Opportunity and Risk
ASHOKLEY	Resource Optimisation and Operational Eco-Efficiency	Opportunity
BHARATFORG	Resource Efficiency and Circularity	Opportunity
MOTHERSON	Product Sustainability and stewardship	Opportunity & Risk
TVSMOTOR	Waste & Recycling	Risk



	Resource Management	Risk
UNOMINDA	Waste Management	Opportunities
EICHERMOT	Product Footprint	Opportunities
	Resource Efficiency and Circularity	Opportunities
	Waste Management	Risk
APOLLOTYRE	Resource Use & Circular Economy	Opportunity
MRF	Toxic Emission and Waste	Risk
BOSCHLTD	Closing products and material loops using secondary materials and raw materials	Opportunity
SUNDRMFAST	Waste Management	Risk
BALKRISIND	Waste Management & Circular Economy	Opportunity
TIINDIA	Waste Management	Risk

Approaches adopted to mitigate the risk identified:

Three of thirteen companies mention compliance with Government regulations as an approach to mitigate the risk associated with circular economy. Tie ups and partnership with authorised agencies and recyclers have been mentioned as an approach by four companies. Optimising the product design has been mentioned only by Exide India Ltd. and Sourcing recycled raw material has been considered only by Appollo Tyres. The Closing of the loop happens when more of recycled content is integrated in the manufacturing process.

Table 5: Risk mitigation efforts.

Company	Excerpts from BRSR
TATAMOTORS	“TML has built a circular economy framework “Tatva”, signifying our commitment to embedding circular economy principles across our entire organization.”
BAJAJ-AUTO	“A)compliance with India’s Plastic Waste Management Rules, 2016 (subsequent amendments) and the Extended Producer Responsibility (EPR) guidelines. B)Establishing robust recycling and reuse programs within the manufacturing facility to divert waste materials from landfill disposal.”



EXIDEIND	“A) The company ensures proper management and disposal of all waste B) Optimised product design, usage, and process re-engineering. C) compliance with Extended Producer Responsibility (EPR) rules and guidelines for battery waste and plastic waste management ”
BHARATFORG	“ESG Committee at the Board level to oversee the implementation of resource efficiency initiatives”
TVSMOTOR	“The company progressively uses more sustainable materials and implements recycling programs”
UNOMINDA	“A) Adhere to the waste management hierarchy reduce and reuse, compost, recycle, waste-to-energy incineration, landfill. B) Dispose of waste through Pollution Control Board authorised vendors”
EICHERMOT	“The company manages waste in accordance with governmental regulations ”
APOLLOTYRE	“The company is also sourcing recycled raw material from suppliers to increase the sustainable raw material content in the product mix”
MRF	“hazardous waste is disposed off through the authorised agencies prescribed under the respective State Pollution Control Board.”
BOSCHLTD	“we endeavor to either create loops directly within Bosch or close them outside the company using established recycling processes.”
SUNDRMFAST	“Through partnerships with authorized agencies, the Company constantly strives to develop mechanisms of recycling and reusing “
BALKRISIND	“We are driving waste management programmes through tie-ups with various recyclers”
TIINDIA	“Waste at all TII's plants are segregated as hazardous and non-hazardous and are disposed in appropriate ways”

Nexus between LCA and Circular Economy:

Six out of seven companies mention Circular economy principles and practices in the details about Risk/ Concerns identified during LCA and action taken. CE comprises in Eco- design and end-of-life product management. Sourcing of recycled raw materials, reducing the amount of raw materials and waste generation, use of recycled materials, extended life of tyre, implementing IMDS, Categorising the components into recyclable and recoverable materials, closed-loop system to reuse water are CE aspects found in the Action taken for the risks identified. Bosch Ltd. identifies Circular Economy as a concern



and mentions LCA in the Action Taken column. The nexus between CE and LCA have been highlighted in the excerpts shown in table 6.

Table 6: Nexus between LCA and CE

Significant social or environmental concerns and/or risks arising from production or disposal of your products/services, as identified in the LCA along with action taken to mitigate the same.		
	Description of Risk or Concern	Action Taken
EXIDEIND	Global Warming Potential and Water Consumption	<ul style="list-style-type: none"> • Energy efficiency initiatives are being taken across facilities • Further increase in sourcing of recycled raw materials used in manufacturing of batteries (Primary focus on Lead and Plastics) • Prioritise wastewater treatment and implement closed-loop systems to reuse water wherever possible. Three of our factories are ZLD(Zero Liquid Discharge) units and we intend to implement this in other factories in the near future.
APOLLOTYRE	Global Warming	<p>The Company has continued its research on tyre weight optimisation to reduce the amount of raw materials used in the raw material acquisition phase, improve fuel economy during use phase and reduce the generation of waste in the disposal phase.</p> <p>The use of renewable or recycled materials, to optimize performance alongside sustainable manufacturing practices are being explored for product development.</p> <p>The Company uses efficient techniques for re-treading truck tyres to provide extended life cycle of the tyre body material to 2-3 times, thus avoiding the need for frequent replacements.</p>
BOSCHLTD	Circular economy and Carbon footprints	Two assessment methods: the fullscale LCA , performed in compliance with ISO 14040 and 14044, and the streamlined LCA , allowing faster assessment of specific issues and drawing on standard database values. In an effort to continuously identify



		further potential to save carbon emissions when developing new products , Bosch e-Bike Systems started using a proprietary LCA processing tool .
HEROMOTOCO	High Fuel Consumption	Replacing with efficient fuel injection system that enables higher fuel atomisation thereby reducing unused fuel wastage and hence substantial reduction in scope 3 emissions.
TATAMOTORS	"Global warming potential Carbon Footprint"	Materials/components with higher carbon footprint contribution identified and action initiated with suppliers.
TVSMOTOR	Complying with the international regulations for the hazardous substances, Depletion of Fossil Fuel, Tailpipe Emission and Climate Change	A) IMDS has been implemented to track, monitor, and quantify the use of substances , complying with the regulatory requirements. B) continuously working on the improvement of CNG-based vehicles. C) Raider 125 motorcycle equipped with Flex-Fuel Technology (FFT) to operate on a blend of ethanol and gasoline, ranging from E20 (20% ethanol) to E85 (85% ethanol).
Bajaj Auto Ltd	"Environmental pollution and mankind harm"	A) Implemented International Material Data System (IMDS), a globally recognized standard in the OEM industry. B) comply with the 'guidelines on provision for End-of-life Vehicles ' (AIS 129 guidelines) C) Registered with the Extended Producer Responsibility (EPR) program D) Component of our vehicles is categorized according to the



		<p>Recyclable and Recoverable category</p> <p>E) compliance with the battery waste management (amendment) rules of 2023</p>
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Conclusion:

With the growing consumption, it has become imperative for the manufacturers to adopt Circular economy practices to address the environmental challenges. As the literature highlights that not all circular economic practices are ecological. This necessitates Life cycle assessment tool which is more comprehensive as it covers all the stages of a products' life cycle whereas CE mainly addresses resource optimisation. LCA undertaken by the automobile sector is still in the nascent stage and needs to address the challenges in conducting LCA.

In an attempt to ascertain the nexus between LCA and Circularity in Indian automobile sector the study supports an argument that LCA is a tool enabling transition to Circular economy which ultimately leads to sustainability. Regulatory compliances and the arrangements with authorised recyclers remain mostly adopted CE strategies while use of recycled materials in the production process remains elusive. The actual closing of the loop is possible with lesser dependence on virgin materials and higher dependence on recycled material.

References:

- Geyer, R., Kuczenski, B., Zink, T., & Henderson, A. (2016). Common Misconceptions about Recycling. *Journal of Industrial Ecology*, 20(5), 1010–1017. <https://doi.org/10.1111/jiec.12355>
- Ha, J., Min, S. K., Hur, T., & Kim, S. (1998). Practical Life Cycle Assessment Methodology for a Whole Automobile. *SAE Transactions*, 107, 2067–2073.
- Hansen, W., Christopher, M., & Verbuecheln, M. (n.d.). *EU Waste Policy and Challenges for Regional and Local Authorities*.
- Haupt, M., & Zschokke, M. (2017). How can LCA support the circular economy?—63rd discussion forum on life cycle assessment, Zurich, Switzerland, November 30, 2016. *The International Journal of Life Cycle Assessment*, 22(5), 832–837. <https://doi.org/10.1007/s11367-017-1267-1>



- Humbert, S., Rossi, V., Margni, M., Jolliet, O., & Loerincik, Y. (2009). Life cycle assessment of two baby food packaging alternatives: Glass jars vs. plastic pots. *The International Journal of Life Cycle Assessment*, 14(2), 95–106. <https://doi.org/10.1007/s11367-008-0052-6>
- Laner, D., & Rechberger, H. (2007). Treatment of cooling appliances: Interrelations between environmental protection, resource conservation, and recovery rates. *Resources, Conservation and Recycling*, 52(1), 136–155. <https://doi.org/10.1016/j.resconrec.2007.03.004>
- Lei, H., Li, L., Yang, W., Bian, Y., & Li, C.-Q. (2021). An analytical review on application of life cycle assessment in circular economy for built environment. *Journal of Building Engineering*, 44, 103374. <https://doi.org/10.1016/j.jobbe.2021.103374>
- Patel, A., & Singh, S. (2022). Implementing circular economy strategies in the automobile industry – a step toward creating sustainable automobiles. *Benchmarking: An International Journal*, 30(7), 2225–2233. <https://doi.org/10.1108/BIJ-08-2021-0486>
- Peña, C., Civit, B., Gallego-Schmid, A., Druckman, A., Pires, A. C.-, Weidema, B., Mieras, E., Wang, F., Fava, J., Canals, L. M. i., Cordella, M., Arbuckle, P., Valdivia, S., Fallaha, S., & Motta, W. (2021). Using life cycle assessment to achieve a circular economy. *The International Journal of Life Cycle Assessment*, 26(2), 215–220. <https://doi.org/10.1007/s11367-020-01856-z>
- Rigamonti, L., & Mancini, E. (2021). Life cycle assessment and circularity indicators. *The International Journal of Life Cycle Assessment*, 26(10), 1937–1942. <https://doi.org/10.1007/s11367-021-01966-2>
- Schwarz, A. E., Ligthart, T. N., Godoi Bizarro, D., De Wild, P., Vreugdenhil, B., & van Harmelen, T. (2021). Plastic recycling in a circular economy; determining environmental performance through an LCA matrix model approach. *Waste Management*, 121, 331–342. <https://doi.org/10.1016/j.wasman.2020.12.020>
- Zabalza Bribián, I., Aranda Usón, A., & Scarpellini, S. (2009). Life cycle assessment in buildings: State-of-the-art and simplified LCA methodology as a complement for building certification. *Building and Environment*, 44(12), 2510–2520. <https://doi.org/10.1016/j.buildenv.2009.05.001>