Procedia
Environmental Science,
Engineering and Management
http://www.procedia-esem.eu

Procedia Environmental Science, Engineering and Management **12** (2025) (4) 1303-1310

28th International Trade Fair of Material & Energy Recovery and Sustainable Development,
ECOMONDO, 4th-7th November, 2025, Rimini, Italy

AN INDICATOR OF CIRCULARITY IN THE CONSTRUCTION SECTOR*

Ottavio Spadaro[1], Agata Matarazzo[1], Costanzo Massimo Riccardo[1], Francesco Garraffo[1], Mariusz Sołtysik[2]

[1]*Department of Economics and Business, University of Catania, Corso Italia, 55, Catania, 95129, Italy*
[2]*Management Process Department, Cracow University of Economics, Krakow, Poland*

Abstract

Circular economy is playing an increasingly central role in sustainability strategies, as it enables the reduction of non-renewable resource use, the minimization of waste, and the mitigation of environmental impacts associated with production and consumption. In this context, it becomes crucial to develop concrete tools to assess how circular a project truly is, thereby guiding more informed design and operational decisions. Among the various sectors under analysis, construction represents a strategic priority for the application of circular economy principles. It is a high-impact sector, responsible for a significant share of global energy consumption, waste generation, and greenhouse gas emissions. Therefore, the promotion of circular practices in construction directly addresses one of the main critical issues of environmental sustainability. However, the current literature still shows shortcomings in providing operational and specific metrics to measure circularity in the construction sector. Many of the existing indicators are too generic or fail to consider the peculiarities of the construction cycle. This study aims to contribute to the scientific discussion by presenting an applied case study that uses as a reference the UNI/TS 11820:2024 standard, recently updated to include indicators more suitable for the construction sector. The study evaluates the environmental, social, and governance circularity of two Sicilian companies operating in the construction sector. One company employs traditional methods, while the other operates in the field of green building and specializes in the construction of timber structures. The study analyzes whether circular economy can positively influence business performance by simplifying cost structures and enabling access to more competitive markets. The level of circularity (CL) will be assessed through a selective application of the indicators from UNI/TS 11820:2024, adapted to the construction context. Data were collected through energy audits, direct observations, financial statements, and ESG questionnaires. Despite the limited sample, the two companies show a growing orientation towards sustainable practices, particularly in energy efficiency, waste management, and the responsible use of water resources. The results confirm that circularity can represent not only an environmental advantage, but also a strategic, replicable, and measurable opportunity for innovation in the construction sector.

Keywords: circular economy, energy impacts, level of circularity, sustainable costruction, UNI/TS 11820:2024

*Selection and peer-review under responsibility of the ECOMONDO

1. Introduction

Circular economy is now one of the most relevant strategic pillars in the development of sustainability policies and in the modification of production models in highly impactful sectors from an environmental point of view. It revolves around a set of principles aimed at resource and waste reduction, while at the same time elongating the life cycle of materials and products, and, in the process, creating more value for the environment, economy, and society. The construction sector is one of the priority areas for the application of circular approaches due to its contribution to the global energy consumption, waste generation, and the emission of greenhouse gases. The integration of practices such as reuse and recycling, modular construction, controlled resource use, and carbon footprint reduction have the potential to greatly improve the environmental and social performance of the entire life cycle of buildings and infrastructure.

There is still a growing interest in more sustainable construction models, however, the technical and regulatory literature points out a lack of specific metrics capable of measuring circularity in this sector with operational and standardized tools. The newly published technical specification, UNI/TS 11820:2024, in this context, offers a refined methodological framework along 71 indicators in the 'core', 'specific', and 'rewarding' categories to assess the circular performance of organizations and products. Using this tool to real case scenarios allows to grasp not only the quantification of Circularity Level (CL) but also scoring of the strengths and weaknesses, thereby greatly aiding investment and management decisions.

In this research, a comparative analysis of two companies working in the construction industry in Sicily, it taking different approaches to production and sustainability integration, will be done in order to evaluate and contrast their ESG's circularity performance using a tailored set of indicators developed from UNI/TS 11820:2024, adjusted to the construction context.

2. Methodology

In terms of methodology, the analysis is subdivided into three main steps: definition of boundaries and selection of relevant indicators, which is followed by data collection, verification, and validation of the data; and, finally, data processing that includes circularity level estimation and result visualization. In the first step, the indicators were based on the framework of reference UNI/TS 11820:2024, which was used to set the range of relevant indicators. Out of the initial 71 indicators, which were organized into six macro-categories, namely: material and components resources, energy and water resources, waste and emissions, product and service logistics, human resources and governance, and infrastructure, as well as the governance of the construction sector, only those with measurable relevance to construction were used.

All of the extracted "core" indicators were mandatory and, as the standards dictate, at least 50% of the "specific" indicators for each section covering "core" indicators must also be incorporated. "Rewarding" indicators were only used when there was supporting documentation or quantitative data available. Phase two focused on the acquisition of primary and secondary data relevant to the activities of the particular company. Primary data were gathered by means of on-site energy audits, which involved the collection of quantitative data regarding construction processes, the production stage and technology used on industrial construction sites, as well as secondary data obtained via technical interviews with managers and staff and completion of ESG" questionnaires. Secondary data was based on company documentation (such as financial statements, procurement data, reports for waste and environmental management, and environmental certifications) and data from measurements conducted by the companies themselves.

For the verification of flows of materials and their traceability, a mass balance approach was used to quantify the measurable and documented estimates of inputs, transformations, waste, and outputs. In the third phase, the Circularity Level (CL) was computed as proposed by the standard UNI/TS 11820:2024, which involves summing the scores of the core, specific, and rewarding indicators, each assigned a distinct weight. The analysis was guided by a circularity framework where each macro-category was computed to ascribe the level of circularity to the company and to also determine the areas of improvement and excellence on the company circularity overall. This provided a basis for developing comparative tables and radar charts which, in turn, aligned with the standard's outlined principles providing an overall and succinct summary of the results for the assessment. Such approach provided a means of combining standardized and regulatory assessments with the operational and supply chain specificities of the construction sector.

3. Case study: Comparison between two companies in the construction sector

This case study focuses on two companies working on the similar projects in Sicily to show two different approaches to the construction business. One is focused on green building while the other specializes in traditional construction. The first company ALFA constructs timber buildings using eco-friendly materials and employs modular construction and offsite fabrication while ensuring energy efficient construction. The second company BETA is involved in traditional construction and deals with the construction of timber buildings using reinforced concrete and other materials. While ALFA has a centralized management approach, BETA has a decentralized structure and focuses on public and private construction contracts with not much regard to efficient resource usage. Such differences in management approaches directly affect the application of the indicators specified in the IVU/TS 11820:2024. The outlined technical specifications consist of 71 indicators in three groups: core indicators which every organization has to fulfill; thematic indicators which must be achieved at least 50% for each thematic group; and awarding indicators which are optional for above and beyond action.

It's worth noting that some indicators cannot be calculated for both companies: some indicators are applicable to only one company, while for the other company those indicators must be considered as not being met. This difference is not a constraint, it simply illustrates how the standard is able to differentiate between more or less advanced circularity production models. For ALFA, the "Material Resources and Components" category has particular relevance. The company uses considerable amounts of FSC and PEFC certified wood, eco-bricks, and low-impact materials, and modular and disassemblable construction solutions. For this reason, the comparative assessment included indicators on the percentage of secondary or recycled materials, the share of sustainably certified materials, and the modularity and disassemblable degree of components. These indicators illustrate the contribution of green building to the reduction of environmental impacts throughout the life cycle. In contrast to BETA, there is a lack or limited availability of data and practices related to these very indicators, mostly due to the dominance of conventional materials and absence of targeted environmental certifications.

For this particular company, the focus was on capturing and applying core indicators of the energy consumed per unit of output, waste, and GHG processes which the standard defines and mandates as fundamental. These indicators are not only easier to compute; they are also more suited for identifying the gains that a 'traditional' company could achieve through the incremental implementation of the circular economy. The indicator that relates to the energy and water resources captured is applicable to both companies but with different outcomes. ALFA is integrated with production systems that use renewable sources such as photovoltaic systems and employs techniques to minimize water use in production. Therefore, ALFA can demonstrate a high performance level in the indicators of the share of renewable energy and water consumed per production cycle. BETA will determine the same indicators with values that approximate zero for renewable sources, and with a more coarse measure for water, demonstrating a sustainability gap. Likewise, in the waste and emissions category, both companies have submittal data, but differing in detail and accuracy.

In terms of adoption and tailoring of formalized waste management systems (MUD, traceability), ALFA integrates recovery and reuse of by-products while BETA confines itself to less detailed, compliant management, reflecting an intermediate level of adoption. This makes recovery of waste and greenhouse gas emission calculations fundamental for comparison. Overall, categories concerning logistics, product, and governance also show more heterogeneity. ALFA, with a short supply chain and local suppliers, reinforced core and specific indicators (with even some rewarding indicators) due to the environmental certifications for products and systems (ISO 9001, ISO 14001, CasaClima). BETA, on the other hand, has an organization with a site management oriented structure with personnel training directed primarily at safety and has no recognized environmental certifications. The selection of comparison indicators was therefore guided by two main aspects: from one hand, the necessity to include core indicators that provide direct and uniform comparison, and from other hand, the opportunity to include specific and rewarding indicators where one of the two companies fulfills the criteria, to illustrate the best practices and the level of innovation achieved. This choice allows the production of a balanced comparative framework, which does not excessively penalize less advanced companies but at the same time highlights the competitive advantage of companies that have invested in more sustainable processes and materials. The next section will present the results of the quantitative and qualitative comparison, showing how differences in production and organizational models translate into measurable circularity values.

4. Results and discussion

The application of UNI/TS 11820:2024 to the two case studies allowed the construction of a comparative indicator matrix, through which it was possible to measure and compare circularity performance. As previously mentioned, the selection included all "core" indicators, more than 50% of the "specific" indicators for each category, and a set of "rewarding" indicators chosen based on relevance and data availability. This approach ensured compliance with the methodological requirements of the standard while adapting to the analyzed construction context. Table 1 presents a summary of the results obtained for each selected indicator, with values expressed on a normalized scale from 0 to 1. A score of "1" corresponds to full compliance with the criterion, while a value of "0" indicates a lack of evidence or non-application. Intermediate values were assigned in cases of partial data or practices not fully consolidated.

In order to convey both qualitative and quantitative data in comparable figures, a normalization operation on a 0–1 scale has been implemented, which complies with the methodological guidelines of UNI/TS 11820. Each indicator has been judged not only from the perspective of its mere existence but also on the level of implementation to a certain extent. The highest score (1.0) was attributed in instances of total conformity and well-established documentation; as the regular utilization of secondary or eco-certified materials by ALFA was the reason that full points were achieved for those indicators concerned with raw materials. ALFA has very efficient practices for energy consumption per unit of output, where energy audits and prefabrication that is sustainable take place, however, due to the fact that the company has not reached full self-sufficiency yet, the maximum score was not given. The value of between 0.8 and 0.9 was assigned in such cases when the company showed that the application was well-established yet it was not complete. If some procedures related to energy and waste are in BETA, which meet standards, but at the same time, due to the lack of advanced monitoring or structured reduction strategies, the company, this is the way in which the indicators on energy and waste management for BETA could receive scores in the range between 0.5 and 0.7.

Table 1. Selected circularity indicators and normalized scores

Category	*Indicators*	*Type*	*ALFA*	*BETA*
Raw materials	% secondary/recycled materials	Core	1.0	0.0
Raw materials	% sustainably certified materials	Specific	1.0	0.0
Raw materials	Component modularity/disassemblability	rewarding	1.0	0.0
Raw materials	Component lifespan	Specific	0.9	0.6
Energy	Energy consumption for unit of output	Core	0.8	0.6
Energy	% energy from renewable sources	Core	1.0	0.0
Energy/water	Water consumption per production cycle	Specific	0.8	0.0
Waste	% recycled or reused waste	Core	0.9	0.6
Waste	Compliant waste management (MUD)	Specific	1.0	0.3
Emissions	CO_2 emissions for unit of output	Specific	0.8	0.5
Logistics	Short supply chain / Transport distance(km)	Rewarding	1.0	0.2
Product	Product certification	Core	1.0	0.0
Product	After-sales service	Specific	0.9	0.6
Product	Design for disassembly	Rewarding	1.0	0.0
Governance	Formalized ESG policies	Core	1.0	0.4
Governance	Sustainability/safety training	Specific	0.9	0.8
Governance	System certifications (ISO/EMAS)	Specific	1.0	0.0

Further, when the practice has existed only in a very limited way or as a mere legal compliance measure without a real management approach to circularity, the score was given in the range of 0.1–0.3. Besides, a 0.0 value was allowed only in cases in which there was no evidence at all or the indicator was not applicable. For instance, BETA is the holder of such indicators referring to FSC or PEFC certified materials, modular design, as well as the share of renewable energy, where the implementation is the least possible. The use of this interpretative scale paved the way for a straightforward comparison of the two companies.

It is not a subjective point, but rather, the way of expressing informational content which is systematic and logical as per the guidelines of the standard. The clear representation of circularity practices was made possible by this: On the one hand, a company like ALFA not only complies with multiple core and specific indicators but also excels in rewarding indicators due to the innovative design and material choice; on the other hand, BETA, a traditional company, obtains a lower score showing that it has especially material and governance issues, but still, it retains the possibility of progress that can be easily noticed in energy indicators and human resources training.On top of the reported scores, the circularity level was calculated according to the UNI/TS 11820:2024 formula.

- ALFA: Sum of scores = 16/17 indicators ≈ 94.1%
- BETA: Sum of scores ≈ 4.6/17 indicators ≈ 27.1%

There is a very large difference between the two companies: the first one gives the circularity level that is more than three times higher than the second, which means that they are significantly different in production and management models. The comparison at the category level allows one to see the advantages and disadvantages that the two companies have. ALFA takes the lead in areas such as materials, modular design, and certifications, which indicates the systematic implementation of eco-building standards and the use of a sustainability framework. Rewarding indicators, e.g., modularity and the design for disassembly, are the major elements that set this company apart, demonstrating that it has not only incorporated the circular flow in the production but also in design philosophy. Contrarily, BETA has the poorest results for almost all indicators. Only energy and human resources training have a positive trend where the company has started the journey of the best practices. Still, the lack of environmental certifications, and the predominant use of traditional materials, and combined with the absence of ESG formalized policies significantly limit the overall performance of the company. The disparity, thus, should not be seen as a cause of punishment of traditional companies but rather as a glimpse of the starting point and the extent of possible movement. The UNI/TS 11820 application helps to identify the degree of difference between the two groups, i.e., those that operate advanced models and the ones that are still in transition, and thus, it provides a strong basis for decision-making in investments, strategies, and innovation pathways.

5. Conclusions

The analysis conducted through the application of UNI/TS 11820:2024 made it possible to assess and compare the circularity level of two companies operating in the construction sector, representing different production models: one based on green building and the use of natural and certified materials, and the other rooted in traditional construction and more oriented toward managing conventional contracts. The results showed a significant gap, with a circularity level of 94.1% for ALFA and 27.1% for BETA. This outcome confirms that design choices, material management, and the adoption of environmental certifications are key factors in enhancing sustainability and circularity performance.

The comparison highlighted how green building, when supported by management and technical practices consistent with circular economy principles, can achieve high performance levels, above the industry average. Indicators such as the percentage of certified materials, component modularity, the presence of renewable energy, and system certifications played a key role in differentiating the two companies. Conversely, lower adoption of ESG policies, the absence of recycled and certified materials, and reliance on conventional energy sources substantially limited the performance of the company focused on conventional construction. However, the results should not be interpreted solely as a static comparison but also as an indication of potential areas for improvement. UNI/TS 11820 provides an operational roadmap that allows companies to identify priority areas for action.

In the case of BETA, the progressive introduction of secondary materials, process certification, and the establishment of formalized ESG policies represent concrete actions that could significantly increase circularity levels in the medium term. For ALFA, the future challenge is to consolidate its competitive advantage by further extending circular practices along the entire value chain, for example by strengthening industrial symbiosis strategies and expanding post-sale services focused on maintenance and reuse. From a broader perspective, this study demonstrates the applicability and effectiveness of UNI/TS 11820:2024 in the construction sector. Despite the sector’s intrinsic complexity, characterized by an articulated supply chain and strong reliance on traditional materials, the standard allows for a quantitative, comparable, and communicable assessment to both internal and external stakeholders.

The possibility of summarizing results into a single circularity indicator, the CL, represents a useful tool both for companies, which can monitor their performance, and for public and private decision-makers, who need reliable metrics to guide policies, incentives, and investment strategies. Looking ahead, integrating UNI/TS 11820 with other regulations and the minimum environmental criteria required at the European level could further enhance its function, promoting convergence toward common standards for measuring sustainability. For the Italian and European construction sector, this would not only mean complying with regulatory and market requirements but also substantially contributing to the objectives of the European Green Deal and the decarbonization commitments for 2030 and 2050.

The comparison between the two case studies highlights that the transition to more sustainable construction models is not only an environmental necessity but also an opportunity for innovation, competitiveness, and resilience for companies in the sector. UNI/TS 11820:2024 proves to be an operational tool capable of measuring, enhancing, and guiding this change. Looking at it from a broader perspective, the study highlights that the UNI/TS 11820:2024 is a viable and effective standard that can be implemented in the construction industry. The standard allows for a quantitative, comparable, and communicable assessment to both internal and external stakeholders, notwithstanding the sector's inherent complexity, which is made up of an articulated supply chain and that is strongly reliant on traditional materials. The fact that results can be summarized in a single circularity indicator, the CL, turns out to be a handy instrument both for companies that can check their performance and for the public and private decision-makers who need trustworthy meters to direct policies, incentives, and investment strategies.

Thinking about the future, harmonizing UNI/TS 11820 with other directives and the minimum environmental criteria mandated at the European level could further extend its role, thus facilitating convergence toward common sustainability measurement standards. For the Italian and European construction sector, this, in turn, would translate not only into the fulfillment of regulatory and market requirements but also into the progress of the European Green Deal objectives and the decarbonization pledges for 2030 and 2050. To sum up, the linking between these two case studies reflects that the switch to more sustainable construction models is a necessity from the environmental perspective; however, it becomes an occasion for innovation, competitiveness, and the capacity of recovery by companies in the sector as well. UNI/TS 11820:2024 is a manifestation of an instrument that can operate, measure, and stimulate this transformation.

References

Amicarelli V., Primiceri M., Misino E., Bux C., (2023), An application of the UNI/TS 11820:2022 on the measurement of circularity in an electrical equipment manufacturing organization in Italy, *Journal of Cleaner Production*, **420**, 138522, https://doi.org/10.1016/j.jclepro.2023.138522

Ardente F., Mathieux F., (2014), Identification and assessment of product’s measures to improve resource efficiency: The case-study of an energy using product, *Journal of Cleaner Production*, **83**, 126–141.

Brunner P.H., Rechberger H., (2017), *Handbook of material flow analysis: For environmental, resource and waste engineers* (2nd ed.), CRC Press, Taylor & Francis Group, Boca Raton, London, New York.

BSI Group, (2017), *BS 8001 – Circular economy: Framework for implementing the principles of the circular economy in organizations – Guide*, British Standards Institution, London.

De Oliveira C.T., Oliveira G.G.A., (2023), What circular economy indicators really measure? An overview of circular economy principles and sustainable development goals, *Resources, Conservation and Recycling*, **190**, 106850, https://doi.org/10.1016/j.resconrec.2022.106850

De Pascale A., Arbolino R., Szopik-Depczyńska K., Limosani M., Ioppolo G., (2021), A systematic review for measuring circular economy: The 61 indicators, *Journal of Cleaner Production*, **281**, 124492, https://doi.org/10.1016/j.jclepro.2020.124492

Geisendorf S., Pietrulla F., (2018), The circular economy and circular economic concepts: A literature analysis and redefinition, *Thunderbird International Business Review*, **60**, 721–731.

Ghisellini P., Cialani C., Ulgiati S., (2016), A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems, *Journal of Cleaner Production*, **114**, 11–32.

Gleason Espíndola J.A., Cordova F., Casiano Flores C., (2018), The importance of urban rainwater harvesting in circular economy: The case of Guadalajara city, *Management Research Review*, **41**, 533–553.

Hughes R., (2017), The EU circular economy package—Life cycle thinking to life cycle law?, *Procedia CIRP*, **61**, 10–16. International Organization for Standardization, (n.d.), *ISO/CD 59004 – Circular economy: Terminology, principles and guidance for implementation*, On line at: https://www.iso.org/standard/80648.html

Jacobi N., Haas W., Wiedenhofer D., Mayer A., (2018), Providing an economy-wide monitoring framework for the circular economy in Austria: Status quo and challenges, *Resources, Conservation and Recycling*, **137**, 156–166.

Kirchherr J., Piscicelli L., (2019), Towards an education for the circular economy (ECE): Five teaching principles and a case study, *Resources, Conservation and Recycling*, **150**, 104406, https://doi.org/10.1016/j.resconrec.2019.104406

Kirchherr J., Reike D., Hekkert M., (2017), Conceptualizing the circular economy: An analysis of 114 definitions, *Resources, Conservation and Recycling*, **127**, 221–232.

Morea D., Fortunati S., Martiniello L., (2021), Circular economy and corporate social responsibility: Towards an integrated strategic approach in the multinational cosmetics industry, *Journal of Cleaner Production*, **315**, 128232, https://doi.org/10.1016/j.jclepro.2021.128232

Passaro P., Perchinunno P., Rotondo F., (2023), Statistical analysis of the circular economy for the intervention policies of the NRRP, *British Food Journal*, **125**, 3121–3140.

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*, **176**, 105916, https://doi.org/10.1016/j.resconrec.2021.105916

Reich R.H., Vermeyen V., Alaerts L., Van Acker K., (2023), How to measure a circular economy: A holistic method compiling policy monitors, *Resources, Conservation and Recycling*, **188**, 106707, https://doi.org/10.1016/j.resconrec.2022.106707

Rossi E., Bertassini A.C., Ferreira C. dos S., Neves do Amaral W.A., Ometto A.R., (2020), Circular economy indicators for organizations considering sustainability and business models: Plastic, textile and electro-electronic cases, *Journal of Cleaner Production*, **247**, 119137, https://doi.org/10.1016/j.jclepro.2019.119137

Sani D., Picone S., Bianchini A., Fava F., Guarnieri P., Rossi J., (2021), An overview of the transition to a circular economy in Emilia-Romagna Region, Italy considering technological, legal–regulatory and financial points of view: A case study, *Sustainability*, **13**, 596, https://doi.org/10.3390/su13020596

Sassanelli C., Rosa P., Rocca R., Terzi S., (2019), Circular economy performance assessment methods: A systematic literature review, *Journal of Cleaner Production*, **229**, 440–453.

Scrucca F., Ingrao C., Barberio G., Matarazzo A., Lagioia G., (2023), On the role of sustainable buildings in achieving the 2030 UN sustainable development goals, *Environmental Impact Assessment Review*, **100**, 107011, https://doi.org/10.1016/j.eiar.2023.107011

Suarez-Eiroa B., Fernandez E., Mendez-Martínez G., Soto-Onate D., (2018), Operational principles of circular economy for sustainable development: Linking theory and practice, *Journal of Cleaner Production*, **214**, 952–961.

UNI – Ente Italiano di Normazione, (2022), *UNI/TS 11820:2022 – Misurazione della circolarità: Metodi e indicatori per la misurazione dei processi circolari nelle organizzazioni*, On line at: https://store.uni.com/uni-ts-11820-2022

UNI – Ente Italiano di Normazione, (2024), *UNI/TS 11820:2024 – Misurazione della circolarità: Metodi ed indicatori per la misurazione dei processi circolari nelle organizzazioni*, On line at: https://www.uni.com/economia-circolare-la-uni-ts-118202024-in-una-nuova-veste/

Veleva V., Bodkin G., (2018), Corporate–entrepreneur collaborations to advance a circular economy, *Journal of Cleaner Production*, **188**, 20–37.