ELIT
Economic Laboratory Transition
Research Podgorica

Montenegrin Journal of Economics

For citation:

Streimikis, J. (2026), "Circularity Performance in Benelux Economies: A Comparative Analysis",
Montenegrin Journal of Economics, Vol. 22, No. 3, pp. 77-88.

Circularity Performance in Benelux Economies: A Comparative Analysis

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ARTICLE INFO

Received April 06, 2025
Revised from April 16, 2025
Accepted July 21, 2025
Available online July 15, 2026

JEL classification: Q01, Q56, 044, 052

DOI: 10.14254/1800-5845/2026.22-3.7

Keywords:
Circular economy,
Benelux,
sustainability indicators,
EU monitoring framework,
comparative analysis

ABSTRACT

This study evaluates the circular economy (CE) performance of the Benelux countries—Belgium, the Netherlands, and Luxembourg—through a comparative analysis of five core indicators derived from the European Commission's CE monitoring framework: material footprint, waste generation per capita, circular material use rate, recycling rate of municipal waste, and greenhouse gas emissions from production activitiesAnalysis of Eurostat data for the years 2013–2022 illustrates marked divergence in circular economy performance among Belgium, the Netherlands, and the EU27 average. Belgium and the Netherlands exhibit comparatively elevated rates of circular material use and recycling, thereby establishing themselves as regional frontrunners in material circularity. Nevertheless, the three coun-tries continue to exhibit pronounced material consumption and waste gen-eration, underscoring stagnation in advancing upstream circularity. These results advocate for intensified policy emphasis on the reduction of con-sumption, the promotion of innovation, and the alignment of circular econ-omy initiatives with overarching climate and sustainability objectives. The research further delineates avenues for subsequent investigation, high-lighting the imperative for more disaggregated, sector-specific, and social-domain analyses to support transitions towards circular economies that are both effective and equitable.

INTRODUCTION

Across Europe, the principle of circular economy has become the organisational core of the sustainable-development strategy, demonstrating that enhanced resource efficiency can underpin long-term economic resilience. The model intentionally decouples value generation from the consumption of finite materials, thereby protecting natural systems, elevating resource efficiency, and reducing net greenhouse-gas emissions (Henrysson and Nuur, 2021). In pursuit of these objectives, the European Union has enacted a tailored Circular Economy Action Plan, which is complemented by transparent performance metrics that track the progress of every Member State.

Within this Union, the Benelux trio-Belgium, the Netherlands, and Luxembourg-has deliberately sought lead status, drawing on dense transport networks, mature legislation, and high public concern for the planet (Hild, 2023; Claudio-Quiroga and Poza, 2024). Even so, although they share borders and similar incomes, their journeys toward circularity have unfolded along different pathways and with uneven

results. A side-by-side look at their performance thus reveals both the forces that propel some policies forward and the barriers that still stall others (Kasztelan, Kijek and Kijek, 2025).
To guide policy evaluation and regional benchmarking, the European Commission has introduced a standardised monitoring framework comprising eleven indicators grouped into thematic areas such as production and consumption, waste management, secondary raw materials, competitiveness, and innovation (European Commision, 2023). While each indicator contributes to a comprehensive understanding of CE performance, this study focuses on five core indicators that most directly capture circularity outcomes and offer measurable, policy-relevant trends over the past decade: Material footprint (resource consumption), Waste generation per capita, Circular material use (CMU) rate, Recycling rate of municipal waste, and Greenhouse gas emissions from production activities. This focus aligns with recent scholarship that encourages moving beyond narrow interpretations of circularity as solely material recovery, toward a broader systemic rethinking of economic design and value creation (Voukkali et al., 2023; Zecca, Pronti and Chioatto, 2023).

The objective of this paper is to assess the circular economy performance of the Benelux countries over the last ten years using these five key indicators, with comparative reference to the EU27 average. In pursuing this examination, we seek to map prevailing trends, discern comparative strengths and weaknesses, and gauge how steadily individual Member States are moving in step with overarching EU objectives. The findings therefore illuminate both the distinctive role that the Benelux countries play in advancing Europes circular economy and the policy gaps that still warrant more deliberate national and cross-border action.

1. LITERATURE REVIEW

In Belgium, the Netherlands, and Luxembourg-the Benelux region-the move toward a circular economy has taken centre stage on Europes sustainability agenda. Because the countries enjoy high incomes, dense infrastructure, and mature institutions, they are well placed to replace the old linear model with a system that keeps materials in steady use. The circular economy thus emerges not simply as an environmental necessity but also as a chance to build resilience, lower reliance on virgin resources, and spark enduring, resource-smart innovation (Kirchherr et al., 2018) (Claudio-Quiroga and Poza, 2024).

The European Union has woven the idea of a circular economy into its most important policies, especially the Circular Economy Action Plan and the wider European Green Deal. Together, these documents set an ambitious agenda, asking Member States to cut waste, use resources more wisely, and reach climate neutrality by 2050. To track progress, the European Commission launched a Circular Economy Monitoring Framework that features eleven key indicators grouped into five areas: production and consumption, waste management, secondary raw materials, competitiveness and innovation, and global sustainability and resilience (European Commission, 2023). By using these shared measures, countries can see how they compare, spot weaknesses, and learn from each other’s successes.

Academic literature highlights that the CE is inherently multidimensional and subject to varying interpretations depending on whether the focus lies on closed-loop processes, economic value retention, or social innovation (Reike, Vermeulen and Witjes, 2017; Streimikis, 2025). It integrates economic, environmental, and social goals and requires coordinated interventions at multiple levels - ranging from industrial redesign and eco-innovation to behavioral change and policy alignment (de Souza, Fröhling and Pigosso, 2023; Alola, Özkan and Uzuner, 2024; Strapchuk et al., 2024). While macro-level indicators are useful for policy monitoring, their implementation also raises questions of interpretability, regional specificity, and sectoral variation (Jakubelskas and Skvarciany, 2023).

The Benelux countries offer an interesting case study in this regard. Belgium and the Netherlands are often identified as front-runners in Europe’s CE transition due to their established recycling systems, high innovation capacity, and supportive legislation. Luxembourg, though smaller, has taken a sectoral leadership role- especially in construction and sustainable procurement- thanks to targeted policies and public-private partnerships (Mihaliková et al., 2018; Hild, 2023).

This study builds upon the broader CE literature by focusing on five key indicators from the EU monitoring framework. These indicators were selected due to their data availability, strong policy relevance, and ability to represent different phases of the circular economy cycle- from input reduction to environmental impact:

1. Material footprint (domestic material consumption per capita) measures the pressure that economic activities place on natural resources. It is considered one of the most comprehensive metrics for assessing resource intensity and decoupling potential (Kulakovskaya et al., 2022).

2. Waste generation per capita reflects consumption patterns and the efficiency of waste prevention strategies. Countries with effective product lifespan extension, reuse systems, and zero-waste strategies tend to score better on this metric (Almansour and Akrami, 2024).

3. Circular material use rate indicates the share of total material inputs that come from recycled waste. It captures the degree to which economies are able to close material loops and reduce dependency on virgin materials (Fura, Stec and Miś, 2020).

4. Recycling rate of municipal waste is critical for measuring the efficiency of end-of-life processes in the circular system. It also reflects local infrastructure, citizen participation, and regulatory effectiveness (Marković, Popović and Marjanović, 2023).

5. Greenhouse gas emissions from production activities per capita establish a link between CE and broader climate objectives. A functioning circular economy is expected to lower emissions by reducing resource extraction, improving energy efficiency, and promoting low-carbon materials (Alola, Özkan and Uzuner, 2024).

Several studies emphasize that CE performance is not only influenced by policies and technology but also by public engagement, education systems, and industrial structure (Uğurlu, 2022; Hild, 2023). For example, countries with high patent intensity in waste management tend to exhibit better CMU rates, while those with decentralized waste governance structures may face challenges in achieving high municipal recycling performance (Kasztelan, Kijek and Kijek, 2025).

Although Belgium and the Netherlands are widely hailed as pioneers of CE policy in Europe (Claudio-Quiroga and Poza, 2024), Luxembourg illustrates how even a compact economy can achieve noteworthy incremental progress by zeroing in on selected industrial segments and value chains (Hild, 2023). Within the Benelux umbrella, cross-border cooperation now serves as a practical platform for sharing lessons, harmonising standards, and mobilising joint capital flows toward climate-smart infrastructure and circular-technology ventures (Mihaliková et al., 2018).

Taken together, the growing CE literature points toward an imperative blend of high-level strategic alignment and finely grained performance tracking at all administrative scales. By isolating five core metrics and benchmarking Benelux countries against the broader EU27 average, the present analysis aims to enrich the regional dialogue on sustainable leadership while providing actionable evidence for future policy adjustment.

2. METHODS AND DATA

2.1. Analytical Framework

This study adopts a comparative performance analysis grounded in the European Commission's *Monitoring Framework for the Circular Economy* (European Commision, 2023). The framework provides harmonized, reliable, and publicly accessible data across five thematic areas and eleven statistical indicators. For the purposes of this study, five key indicators were selected based on relevance, interpretability, and coverage: Material Footprint, Waste Generation, Circular Material Use Rate, Municipal Recycling Rate, and GHG Emissions from Production.

The study applies a descriptive longitudinal analysis approach covering the period from 2013 to 2022, with a focus on the Benelux countries (Belgium, Netherlands, Luxembourg) and EU27 as a benchmark.

2.2. Data Sources and Coverage

All data were retrieved from Eurostat, the statistical office of the European Union. The selected indicators were downloaded in .tsv and .xlsx formats directly from the Eurostat CEI database (Eurostat, 2024). The dataset includes annual values for all five indicators, ensuring full temporal coverage from 2013 to 2022 for each country in the analysis.
Data were cleaned, validated, and transformed using Python (Pandas and Matplotlib) for consistency and visualization. Where multiple data entries for one country existed (e.g., breakdowns by sector), only the aggregate national values were used.

2.3 Indicator Selection and Interpretation

Indicator selection was based on three main criteria:

· Relevance to core CE goals (material efficiency, decarbonization, recycling),
· Comparability across EU Member States and years,
· Availability of consistent time-series data for Benelux countries and EU27.

Each indicator was interpreted in line with European Commission guidelines:

· Material Consumption: Measured in kilograms per capita (kg/cap), reflecting direct and indirect material use.
· Waste Generation per Capita: Total waste produced annually by households and businesses per person.
· Circular Material Use Rate: Share (%) of material inputs derived from recycled or reused sources.
· Recycling Rate of Municipal Waste: Proportion (%) of municipal solid waste recycled.
· GHG Emissions from Production: Total greenhouse gas emissions (CO_2 eq.) per capita from production sectors.

2.4. Comparative Analysis Approach

The empirical analysis relies on visual comparison via bar charts for each indicator across the selected countries and years. This approach helps:
· Trace temporal trends within each country,
· Compare relative performance between Benelux countries and the EU27 average,
· Identify convergence or divergence in circularity trajectories.

Descriptive statistics are supported by qualitative insights from policy literature to contextualize performance differences.

2.5 Limitations

Several limitations should be acknowledged:
· Data gaps or lags may affect consistency, especially in newer indicators.
· Normalisation to a per capita basis fails to differentiate among economic structure and industrial composition, which can yield markedly divergent emission and material flow trajectories.
· The analytic framework intentionally abstracts from direct indicators of policy enactment, innovation outputs, or shifts in individual and collective behaviour, necessitating the integration of qualitative inquiry for a complete assessment.

· The five indicators selected, while comprehensive, do not fully capture social and institutional dimensions of the CE transition.

Despite these constraints, the selected indicators provide a robust empirical foundation for comparative evaluation and offer valuable insights for policy alignment and performance benchmarking.

3. CASE STUDY RESULTS

This section undertakes a systematic comparison of circular economy performance in Belgium, the Netherlands, and Luxembourg for the period 2013 to 2022. The assessment utilises five primary indicators delineated in the European Commission's Circular Economy Monitoring Framework, specifically addressing resource consumption, waste creation, material circularity, recycling efficiency, and emissions from production processes.

Each subsequent sub-section delineates the temporal evolution of these indicators, measured against the EU27 mean. Graphical displays are supplemented by analytical commentary that elucidates intra-regional advancement, relative standing, and coherence with circular economy targets throughout the Benelux area.

3.1 Material Footprint Indicator

The material footprint (MF) is a quantified measure of the global mass of raw materials—comprising biomass, fossil fuels, metal ores, and non-metallic minerals—extracted to satisfy a country's final consumption. It thus enables an assessment of resource use framed by the distribution of consumption rather than production. During the period from 2013 to 2022, the Benelux countries exhibited marked oscillations in MF, reflecting differentiated structural and economic trajectories within the region. The accompanying Figure 1 below contrasts MF trajectories for Benelux with EU27 aggregates over the same interval.

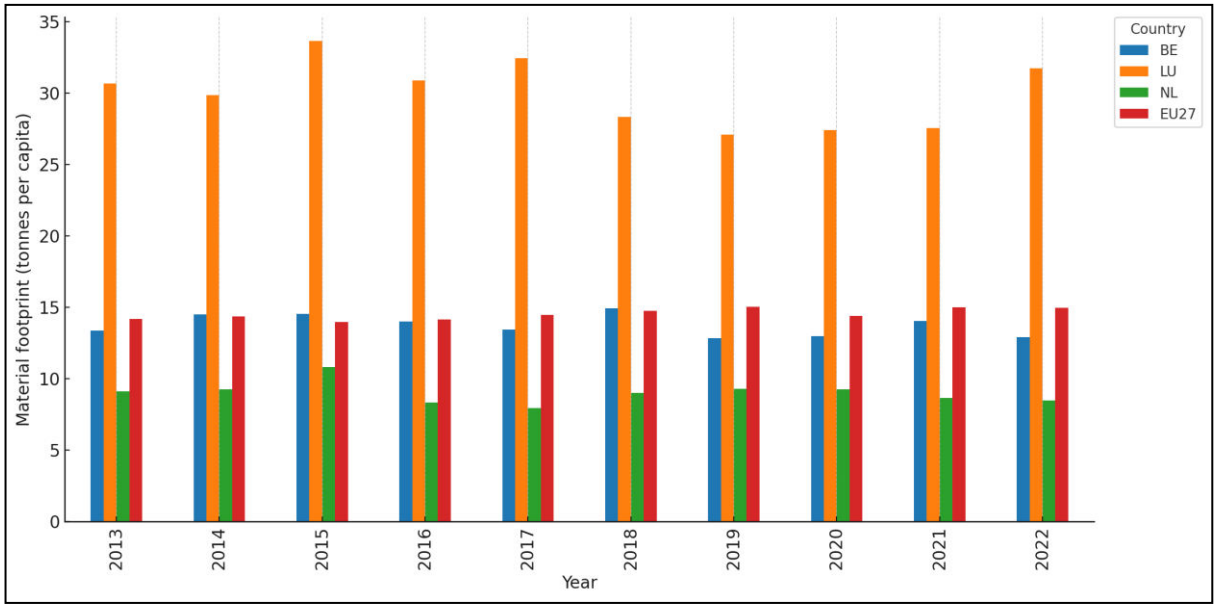

Figure 1. Material Footprint per Capita in Benelux Countries and the EU27 (2013–2022)
Source: Made by the author based on Eurostat dataset cei_pc020*)*

As one can see from the graph above, Luxembourg consistently reported the highest MF per capita in the region — regularly surpassing 30 tonnes per person - a figure more than twice the EU27 average, which fluctuated around 14-15 tonnes during the same period. Luxembourg's elevated material footprint per capita is primarily a consequence of its diminutive population, substantial GDP per capita, and a services-

dominated economy that encompasses resource-intensive infrastructural investments. Although year-on-year figures display limited variation, the national footprint has remained stubbornly high, lacking any clear and persistent decrease over the last ten years.

Belgium and the Netherlands record more moderate, yet consistently elevated, per capita material flows that exceed the EU27 average throughout the entire decade. Belgium's figures cluster between 18 and 20 tonnes, while the Netherlands' range is 15 to 17 tonnes. Both countries register minor absolute reductions in later years, although a pronounced contraction in 2020 correlates with the temporary economic sluggishness induced by the COVID-19 pandemic. Subsequent rebounds in material throughput, however, indicate that the reductions were transitory rather than structural.

The absence of durable decreases across the Benelux trio implies that prevailing circular economy policies are inadequate to sever the linkage between material consumption and GDP expansion. Their sustained divergence above the EU27 average further suggests that, despite leadership in recycling and technological ingenuity, upstream material intensity remains unresolved. A genuinely circular transition requires the region to shift attention from end-of-pipe waste management toward the systemic redesign of consumption patterns and the active promotion of dematerialisation.

3.2. Waste generation per capita

Waste generation per capita reflects the average amount of waste produced by each individual within a country and serves as a key proxy for consumption intensity and resource efficiency. An effective circular economy aims to reduce this value over time through material reuse, reduced consumption, and improved product design. Benelux and EU27 data from 2013 to 2022 are presented in the Figure 2 below.

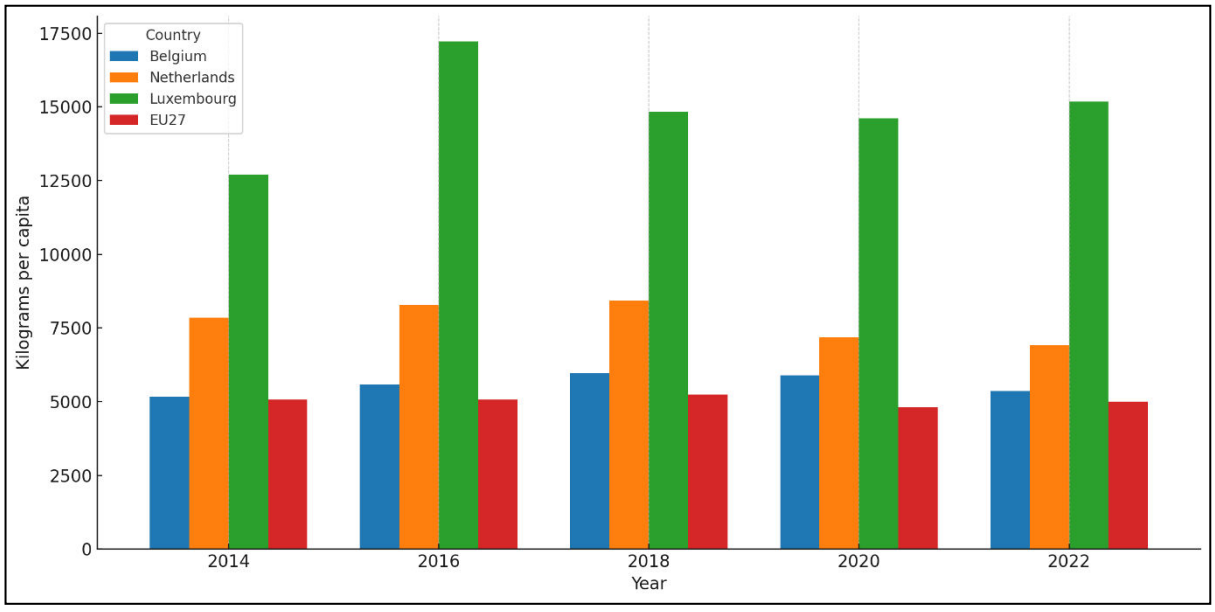

Figure 2. Waste Generation per Capita in Benelux Countries and the EU27 (2013–2022)
Source: Made by the author based on Eurostat dataset cei_pc035

As shown in the graph above, between 2013 and 2022, the Benelux nations produced waste at levels higher than the EU27 mean, which hovered close to 530 kg per inhabitant. Luxembourg remained the highest, with per capita figures that climbed from 660 kg to 780 kg, a reflection of its wealth and persistent difficulties in curtailing waste. The Netherlands produced waste that ranged from 560 kg to 620 kg per inhabitant, while Belgium occupied a tighter band of 570 to 610 kg.

A closer look at the trend data reveals that none of the three countries achieved a persistent decline. Instead, the observed year-on-year changes imply that policy interventions have not yet redetermined

consumption practices or waste generation in the domestic sector. Luxembourg presented the widest annual swings, Belgium registered small reductions toward the end of the period—likely the consequence of public education initiatives and adjustments to waste pricing. Still, these developments fall short of bridging the divide to EU waste reduction benchmarks or of advancing the transition to a circular economy.
In comparison, the EU27 average remained more stable and consistently lower than all Benelux members. This disparity underlines the urgency for more aggressive upstream interventions in product design, packaging regulation, and household awareness in Benelux states, especially if they are to position themselves as regional leaders in circularity.

3.3. Circular Material Use Rate

The circular material use rate measures the proportion of material resources consumed in the economy that originate from recycled waste materials—essentially capturing how efficiently secondary raw materials are reintroduced into economic flows. A higher CMU rate reflects improved circularity, reducing the need for virgin material extraction. Benelux and EU27 data from 2013 to 2022 are presented in the Figure 3 below.

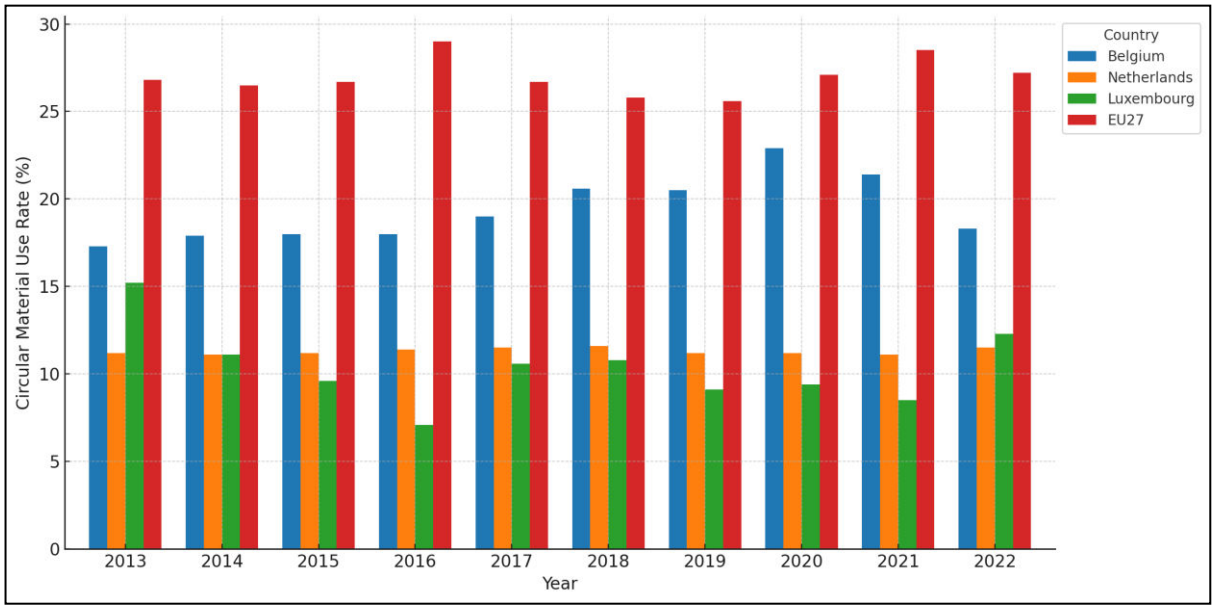

Figure 3. Circular Material Use (CMU) Rate in Benelux Countries and the EU27 (2013–2022)
Source: Made by the author based on Eurostat dataset cei_srm030

Among the Benelux countries, the Netherlands registers the highest circular material utilisation (CMU) rates within the EU, consistently recording values between 25% and 31% from 2013 to 2022. This achievement reflects the maturity of the nation's recycling networks and ongoing initiatives to reincorporate recovered materials into production cycles. Belgium's rates, varying from 18% to 23% over the same interval, marginally exceed the EU27 average, which remained stable between 11% and 12%. This above-average performance signals Belgium's continued investment in industrial symbiosis initiatives and the optimisation of material recovery pathways.

Contrastingly, Luxembourg's CMU rates, predominantly between 8% and 10%, lie below the EU27 indicative of weaker circular practices. The limited industrial footprint and reduced volume of waste generated per capita restrict the pool of recyclable material available for domestic processing, contributing to the observed shortfall.

Thus, the Benelux region reveals heterogeneous circular performance: the Netherlands and Belgium set benchmarks above EU27 norms, while Luxembourg's compact dimensions and economic profile attenuate its circular capacity. Enhancing the region's collective CMU outcomes will necessitate targeted

interventions in Luxembourg, particularly in expanding circular public procurement and scaling recovery operations in high-impact sectors such as construction and municipal service delivery.

3.4. Recycling Rate of Municipal Waste

This indicator captures the share of total municipal waste that is recycled, reflecting how effectively household and urban waste streams are managed. Recycling is central to circularity, allowing resources to be kept in use and reducing landfill dependency. Figure 4 below presents Benelux and EU27 data from 2013 to 2022.

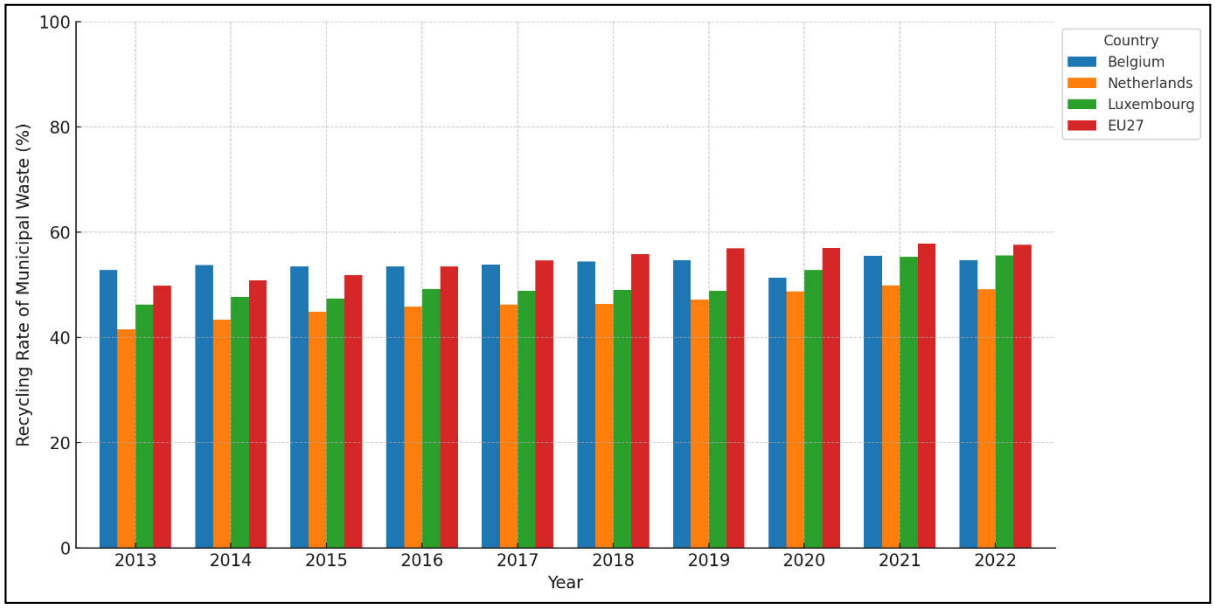

Figure 4. Recycling Rate of Municipal Waste in Benelux Countries and the EU27 (2013–2022)
Source: Made by the author based on Eurostat dataset cei_wm011

As one can see from the graph above,from 2013 to 2022, the Netherlands sustained the highest recycling rates in the Benelux region, achieving levels that fluctuated between 53% and 60%. Belgium recorded slightly lower rates, uniformly situated between 50% and 57%, yet both countries surpassed the EU27 average, which edged upward from 42% in 2013 to 49% in 2022. Such persistent performance reflects the impact of calibrated investments in recycling infrastructure, well-organised waste separation networks, and sustained outreach to the public.

Luxembourg, in contrast, reported recycling rates that generally hovered between 45% and 50%, albeit with a discernible upward trajectory over the period. While the country did not match the performance of its immediate neighbours, its rates remained above the EU benchmark and exhibited a slow but steady convergence by 2022.

The data reveals a positive but uneven trend: all three Benelux countries maintained or improved their recycling rates, outpacing the EU average. However, future improvements may require tackling more complex waste streams - such as composites and multi-material packaging - along with further behavioral shifts in households and businesses. Continuous policy innovation and digital tools for waste tracking could enhance recycling quality and consistency across the region.

3.5. GHG Emissions from Production

This indicator reviews the climate impact of national production sectors by quantifying territorial greenhouse gas emissions, explicitly omitting land-use change and international transport emissions. Although emissions accounting does not constitute a measure of circularity per se, greenhouse gas releases deliver

essential information regarding the overall environmental sustainability and production efficiency of economic systems. The Figure 5 below depicts emissions data for the Benelux and for the EU27, covering the period from 2013 to 2022.

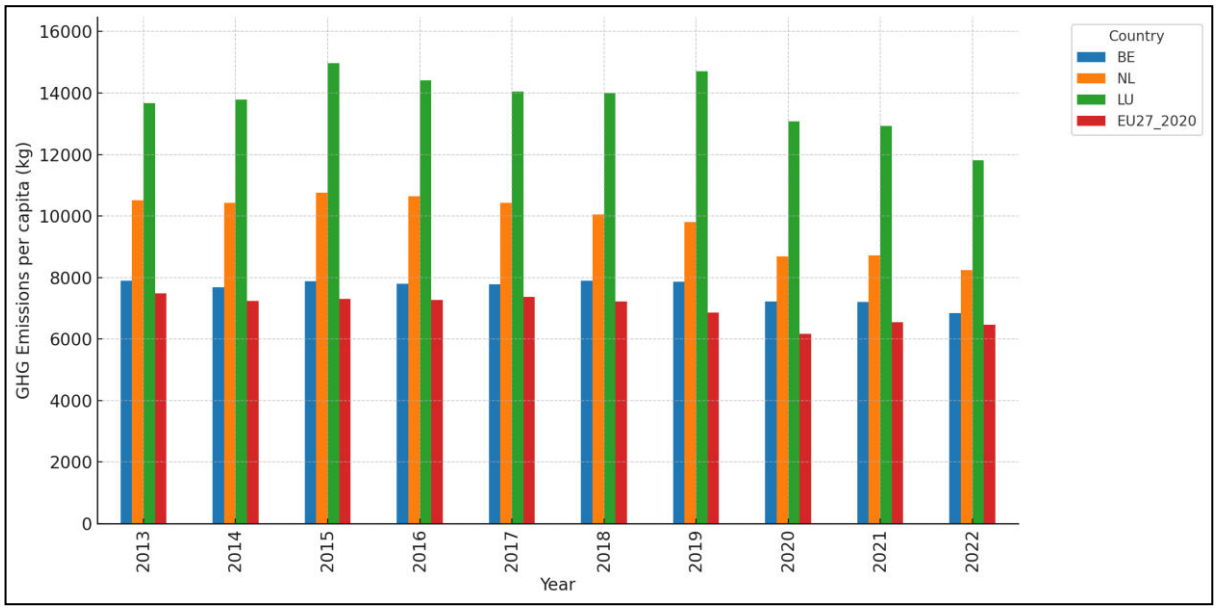

Figure 5. Greenhouse Gas Emissions from Production Activities in Benelux Countries and the EU27 (2013–2022)
Source: Made by the author based on Eurostat dataset cei_gsr011.

As shown in the graph above, in 2013, Belgium recorded the highest GHG emissions among Benelux countries at over 95 million tonnes of CO_2-equivalents, followed by the Netherlands at roughly 90 million, and Luxembourg with just under 10 million tonnes. Across the decade, all three countries managed to reduce emissions, though at varying rates.

By 2022, Belgium's greenhouse gas emissions fell to roughly 81 million tonnes, representing an approximate 15 percent drop; the Netherlands reported a decline to 77 million tonnes, corresponding to a reduction of around 14 percent, while Luxembourg posted a minor reduction to 8.5 million tonnes. Collectively, emissions across the EU27 contracted at an approximate rate of 20 percent during the same timeframe, a development partly attributable to sectoral decarbonisation sweeps in energy and manufacturing that were especially pronounced in parts of Eastern and Southern Europe.

Although these countries posted absolute reductions, their emissions remain abnormally high when benchmarked against population numbers, a situation most pronounced in Belgium and the Netherlands. Such outcomes underline a continued dependence on energy-intensive industrial activities and fossil fuel-derived production pathways. To ensure that circular economy initiatives harmonise with long-term climate-neutrality aspirations, the Benelux nations must hasten the deployment of low-carbon production technologies and deepen circular practices in emissions-intensive domains, notably construction, transportation, and the energy sector.

4. DISCUSSION

Assessment of circular economy metrics across the Benelux region discloses a stratified, dynamic, and occasionally fractious landscape with respect to compliance with EU sustainability frameworks. Belgium, the Netherlands, and Luxembourg exhibit well-articulated policy architectures and supportive circularity-oriented infrastructures; however, the velocity and character of advancement diverge markedly across the employed metrics.

The reported material footprint data highlight a persistent disjunction between GDP growth and resource productivity. All Benelux countries maintained per capita figures above the EU27 mean during the past decade, with Luxembourg recording especially elevated levels. These outcomes indicate that, even as circular programmes continue to unfold, upstream resource extraction and consumption have yet to be decisively curtailed. Such conclusions corroborate earlier investigations documenting the persistent challenge of dissociating material throughput from the growth trajectories of affluent economies (Claudio-Quiroga and Poza, 2024; Kasztelan, Kijek and Kijek, 2025). They also align with scholar's findings, that stress that circular economy policies still struggle to decouple economic expansion from environmental degradation at the EU level (Zecca, Pronti and Chioatto, 2023; Radivojević, Rađenović and Stanojević, 2024).
Likewise, per capita waste generation in the Benelux countries consistently exceeded the EU average, with Luxembourg registering the highest per capita total. The stable or upward trajectory observed in both Belgium and Luxembourg indicates that advancements in waste processing are insufficiently complemented by declines in waste generation. This divergence signals an imperative for augmented policy measures concentrating on sustainable consumption and production patterns (de Souza, Fröhling and Pigosso, 2023; Alola, Özkan and Uzuner, 2024).

In contrast, the circular material use rate suggests a more encouraging trajectory. The Netherlands stands out as the clear leader, achieving a CMU rate that is almost three times the EU27 mean. Belgium achieved slight, yet notable, advancements, while Luxembourg's rate remained comparatively low and unchanged. The exceptional Dutch result is attributed to robust policy frameworks that promote industrial symbiosis, the use of secondary raw materials, and the design of circular products. These outcomes corroborate earlier analyses identifying the Netherlands as the foremost European nation in comprehensive circularity (Alola, Özkan and Uzuner, 2024).

The recycling rate of municipal waste reinforces the observation that the Benelux countries excel in the latter stages of waste management. Belgium and the Netherlands consistently exceed the EU average, with recycling rates either stable or trending upward. Luxembourg, despite ranking below the other two, has recorded recent improvements, suggesting that ongoing investments in recycling infrastructure and in public education initiatives are beginning to yield dividends (Hild, 2023).

In summary, emissions associated with industrial production reveal interplay between underlying economic composition and prevailing energy regulation regimes. The Netherlands and Belgium recorded marginal declines in gross GHG output, yet these reductions lag behind the EU-wide trajectory. By contrast, Luxembourg's steeper, sustained decrease is noteworthy. Such divergent patterns imply that energy-dependent industries continue to impose elevated environmental loads within the broader Benelux region, underscoring the necessity of co-integrating circular economy initiatives with low-carbon energy transformation pathways (Jakubelskas and Skvarciany, 2023).

Taken together, these results suggest that while the Benelux countries exhibit strong performance in recycling and circular material use, they struggle with reducing overall resource consumption and waste generation. This imbalance indicates a partial circular transition- focused more on end-of-life recovery than on rethinking production and consumption systems. Achieving greater circularity will require a systemic approach, including more aggressive eco-design standards, green public procurement, and incentives for waste prevention and reuse (Kennedy and Linnenluecke, 2022).

Moreover, the sustained gaps between Luxembourg and its Benelux neighbours across multiple metrics underscore the role of economic scale, sector mix, and innovation capability in determining circular economy performance. Coordinated regional initiatives centred on data standardisation and joint investments stand to mitigate such divergences and amplify the collective circular-economy potential of the Benelux partnership.

CONCLUSION

This analysis examined the circular economy performance of the Benelux states through the EU's five operational indicators, measuring resource potency, waste dynamics, material reincorporation, recycling efficacy, and emissions intensity. Comparative trends since 2012, set against the EU27 baseline, indicate that the region is on a cautiously encouraging, albeit asymmetric, circular-path trajectory.

Belgium and the Netherlands have each realised meaningful enhancements in the sophistication of their circular structures, particularly regarding recycling metrics and the utilisation of reclaimed materials. These gains rest on resilient institutional ecosystems, dynamic public-private alliances, and a culture of eco-innovation. The Netherlands distinguishes itself as a regional high performer in material reincorporation, while Luxembourg, notwithstanding concentrated policy interventions, continues to trail on nearly every indicator, the shortfall traced largely to its size and sector-specific structural rigidities.

However, the assessment reveals notable deficiencies, particularly in material footprint and waste generation, with all three nations surpassing the EU27 benchmark. Such results imply that circular economy policies are presently skewed toward terminal recovery stages, inadequately addressing earlier levers like product design, reuse, and the promotion of sustainable consumption practices. Furthermore, the sluggish trajectory of greenhouse gas emissions decline in manufacturing underscores the necessity of synchronising circular economy measures with more stringent climate governance.

Future research directions should aim to:

· Investigate the sector-specific drivers of circularity in Benelux countries, such as construction, manufacturing, and agriculture;

· Assess the effectiveness of policy instruments, including fiscal incentives, procurement policies, and regulatory frameworks that aim to reduce resource use;

· Explore the social dimensions of circularity, including consumer behavior, education, and labor market impacts;

· Develop composite indicators or CE indexes that integrate environmental, economic, and social outcomes to better assess the quality of circular transitions;

· Conduct longitudinal and scenario-based modelling to anticipate future pathways and trade-offs in CE performance under different policy and market conditions.

To summarise, the Benelux countries constitute an advanced subgroup within the EU's movement towards a circular economy; however, continued advancement will require integrated approaches, improved transnational coordination, and a sharpened emphasis on alleviating resource consumption from the outset. Embedding circular principles within the wider sustainability framework - including climate adaptation and social justice - remains critical to achieving durable ecological integrity and economic viability over the long term.

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