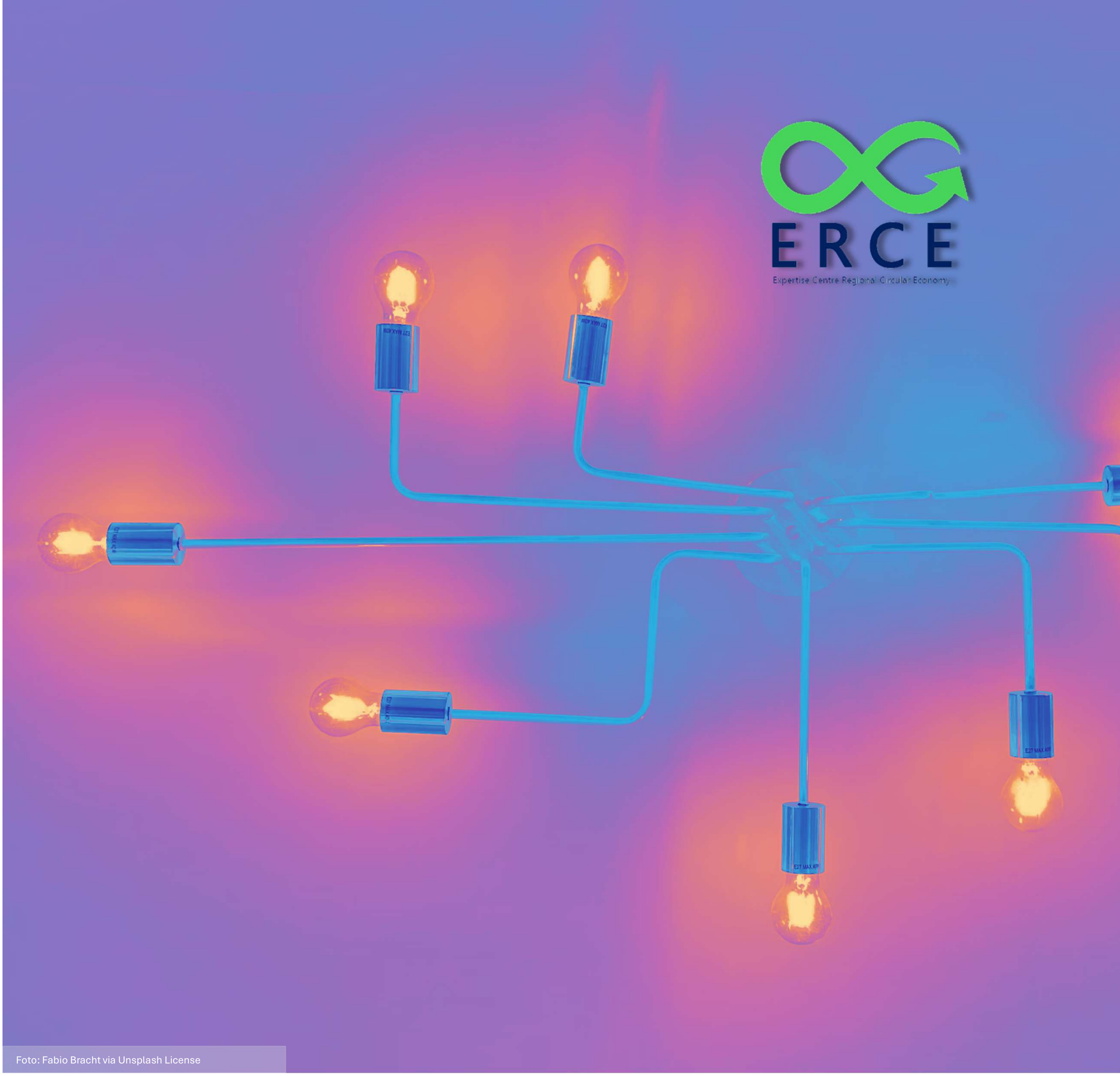

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Towards a Circular Limburg: Material Flows, Environmental Impacts, and Systems of Provision

English Translation

This report provides an integrated insight into the material flows, waste streams, and environmental impacts of the Limburg economy, serving as a foundation for accelerating the circular transition. The analysis shows that North, Central, and South Limburg each have distinct material profiles, with different opportunities and challenges for circularity. By linking material use to societal systems such as the food system, the report offers a broader perspective on sustainability, well-being, and resilience. It therefore provides a basis for defining regional priorities and developing targeted circular strategies for Limburg.

Link: Originele Nederlandse Versie

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Towards a Circular Limburg: Material Flows, Environmental Impacts, and Systems of Provision

Executive Summary

The transition of Limburg towards a circular society requires a clear, detailed, and accessible understanding of how materials flow through the regional economy, where waste is generated, and the environmental pressures associated with these processes. This report, developed through a collaboration between ERCE and Structural Collective, provides this insight for the Province of Limburg through a model of material demand and supply covering all businesses in the region, based on registered waste data from 2024. These flows are linked to associated CO_2 emissions, water consumption, and land use. A distinction is made between North, Central, and South Limburg, as each subregion has its own characteristic economic profile. In addition, the conventional sector-based classification of economic activity is complemented by a systems of provision perspective (such as food, mobility, clothing, and housing), making visible how material use is connected to concrete societal needs.

The analysis reveals a material-intensive and regionally differentiated economy. Agriculture, food production, and biomass play a more prominent role in North Limburg; Central Limburg is more strongly characterised by mineral extraction and construction materials; and South Limburg exhibits the largest and most industrially concentrated material use, with chemical products and fertilisers particularly prominent. Registered waste streams are dominated by mineral materials, especially those related to construction activities. Treatment pathways vary by material type: contaminated soil and rubble account for a large share of transport and storage activities, while concrete, stone, gypsum, and asphalt constitute a substantial proportion of mechanically recycled materials. In terms of mass, household residual waste is considerably smaller than these mineral flows and is processed primarily through thermal treatment.

When looking beyond physical volumes, the picture changes significantly. Mineral and construction materials dominate material throughput and waste generation by weight, but these flows play a less prominent role when viewed through the lens of environmental impact. Industrial and chemical materials, including plastics, contribute more substantially to CO_2 emissions, while food and biomass-related materials account for a significant share of water consumption and land use. We therefore regard environmental impact as an important complementary perspective for setting strategic and policy priorities: material volumes, waste generation, and environmental pressures each reveal different challenges and intervention points.

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The systems of provision perspective broadens the analysis by linking material flows to the societal needs they support. The example of food illustrates how circularity extends across entire systems of production, processing, logistics, retail, and consumption, while intersecting with economic value creation, innovation, health, broad well-being, and resilience. The food system generates substantial added value and employment in the region, while innovation ranges from alternative proteins and healthy nutrition to the valorisation of residual streams and bio-based value chains. At the same time, access to healthy food and a healthy living environment is not equally distributed among the residents of Limburg. If the circular transition is viewed as a means to promote broad well-being for all citizens, these dimensions must also be considered within the analysis.

In summary, the findings highlight the importance of accelerating Limburg's circular transition through an approach that builds on region-specific characteristics. By combining material flows, environmental impacts, and systems of provision within a single analytical framework, a robust foundation is created for identifying regional priorities and designing strategies that reduce resource demand and environmental pressures while supporting resilient regional socio-economic development. We therefore present this report as an invitation to regional stakeholders engaged in the circular transition to jointly establish priorities for the circular economy and, in doing so, accelerate the transition across Limburg as a whole.

Introduction

The circular transition is increasingly taking shape at the regional level, where national and European ambitions are translated into concrete action. Regions provide the practical context in which governments, businesses, knowledge institutions, civil society organisations, and citizens can align their efforts and embed circular strategies within specific economic structures, material flows, and societal priorities. Strategies such as circular design, repair, reuse, sharing, and recycling emerge through attention to the specific opportunities, challenges, material dependencies, and institutional capacities of a particular region.

A comprehensive understanding of the regional context is therefore essential for advancing the circular transition. This requires insight into how resources enter and circulate through the regional economy, which activities drive material use, when and where materials become waste, and the environmental pressures associated with these flows. Equally important is understanding how material use relates to the societal needs that economic activities ultimately serve. This connects the physical dimensions of circularity with its broader objective: meeting societal needs with lower material demand and reduced environmental pressure while contributing to broad well-being and resilience within planetary boundaries.

This report develops the empirical foundation for such a perspective in Limburg through a collaboration between Structural Collective and the Expertise Centre for Regional Circular

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Economy (ERCE). Its foundation is a Material Flow Analysis (MFA) that maps material use and material supply within the provincial economy, distinguishing between North, Central, and South Limburg. The analysis is complemented by registered waste flows and their treatment pathways, as well as an environmental impact assessment focusing on CO_2 emissions, water consumption, and land use. Together, these dimensions provide a reference framework for Limburg's material economy by mapping both the scale and composition of resource use and the associated environmental pressures.

The analysis is subsequently expanded from economic sectors to systems of provision, linking material use to the societal needs supported by interconnected economic activities, with the food system serving as an illustrative example. This perspective complements the Material Flow Analysis by relating the material organisation of Limburg's economy to the functions it ultimately fulfils. It thus provides a foundation for understanding the regional circular transition from a systems perspective.

The report consists of three parts. Chapter 2 provides a concise overview of the research approach and data sources, while the detailed methodology is presented in the appendix. Chapter 3 presents the main findings regarding material use and supply, regional differences between North, Central, and South Limburg, registered waste streams and treatment pathways, and the environmental impacts associated with different materials. Chapter 4 broadens the analysis through the systems of provision perspective, examining how material use and environmental pressures relate to the fulfilment of societal needs. Food provision in Limburg is used as an illustrative example connecting circularity with economic activity, innovation, broad well-being, and resilience. In the future, and in collaboration with regional stakeholders, this perspective will also be extended to other societal domains, including mobility, healthcare, clothing, housing, and recreation.

Research Approach and Data Sources

The Material Flow Analysis was developed to establish a quantitative reference framework for the material flows associated with the Limburg economy. The analysis provides insight into material use and supply, waste generation and treatment, and the environmental pressures associated with material inputs. It covers the Province of Limburg for the reference year 2024 and, wherever permitted by the available data, distinguishes between North, Central, and South Limburg. This regional differentiation is important because economic activities and material profiles vary considerably across the COROP regions.

The methodology combines three complementary approaches. Material use and material supply are estimated through a top-down approach, translating national sectoral material intensities to the Limburg economy using regional data on business establishments and employment. Waste flows are analysed through a bottom-up approach based on individual registered waste records

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originating from Limburg. Environmental impacts are subsequently linked to material inputs. Together, these components connect Limburg's economic structure with the materials it uses and supplies, the waste it generates, and the environmental pressures associated with material consumption.

The analysis combines several datasets that provide complementary information on economic activity, materials, and waste. The LISA business register supplies establishment-level information, including location, economic activity according to the Dutch Standard Industrial Classification (SBI), and employment figures. The CBS Material Monitor, combined with CBS employment statistics, provides national estimates of material use and material supply per employee by economic sector. CBS population data are used to estimate household material flows. Finally, the National Waste Registration System (LMA) provides individual registrations of reported waste streams. Supporting datasets are used to harmonise postal codes, sector classifications, material categories, waste categories, and waste-treatment methods across these different sources.

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3. Key Findings

3.1 Material Flows and COROP Profiles

At the provincial level, Limburg's material economy is characterised by substantial flows of mineral resources, biomass, food products, chemical substances, and construction materials. Industry plays a central role in both material use and material supply, alongside extractive industries, agriculture, and the construction sector (Figure 1). Within this provincial picture, the three COROP regions display distinct material profiles.

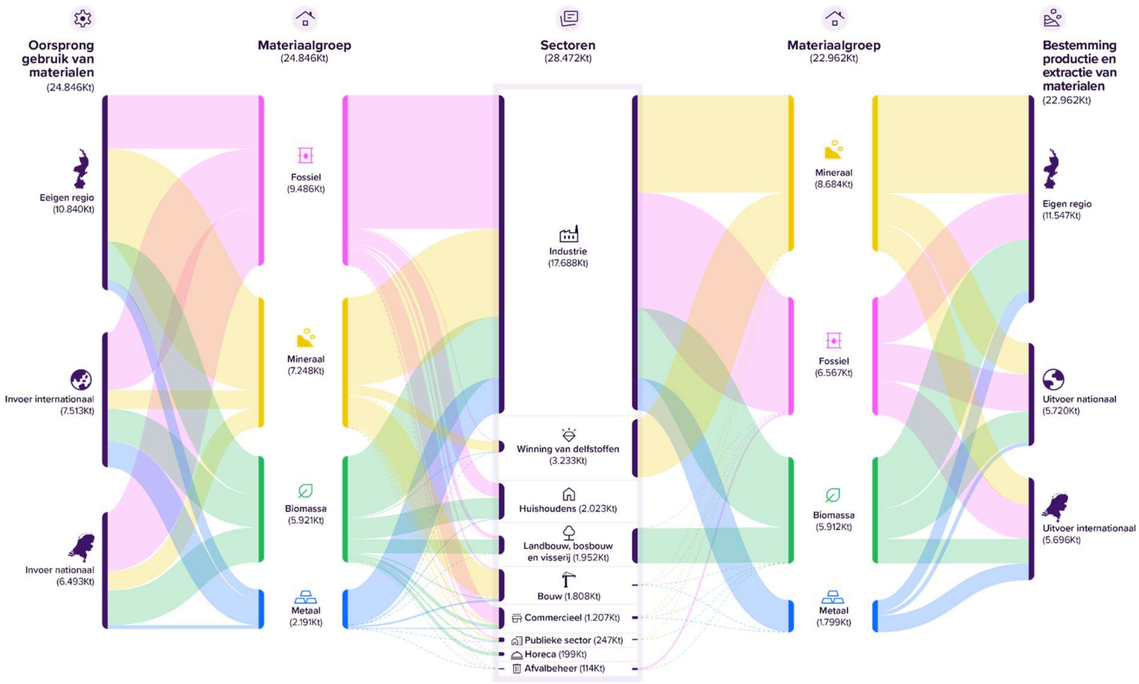

Figure 1. The economie of Limburg in Material Flows[1]

North Limburg has a relatively diversified profile, with approximately 5.6 Mt of material use and 5.4 Mt of material production and extraction (Figure 2). Here, a megaton (Mt) represents one million tonnes of material mass. Compared with the other regions, agriculture, forestry, and fisheries occupy a particularly prominent position, resulting in substantial flows of food products and biomass alongside industrial and construction materials.

[1] For this visualisation with import- and export data. The MFA analysis is combined with CBS study: 'De goederenstromen van de provincies 2015-2022'.

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Central Limburg, with approximately 5.3 Mt of material use, is characterised more strongly by mineral extraction and construction materials (Figure 3). The local extraction of sand and gravel is closely linked to construction and mineral-processing activities, giving the region a distinct resource-based profile.

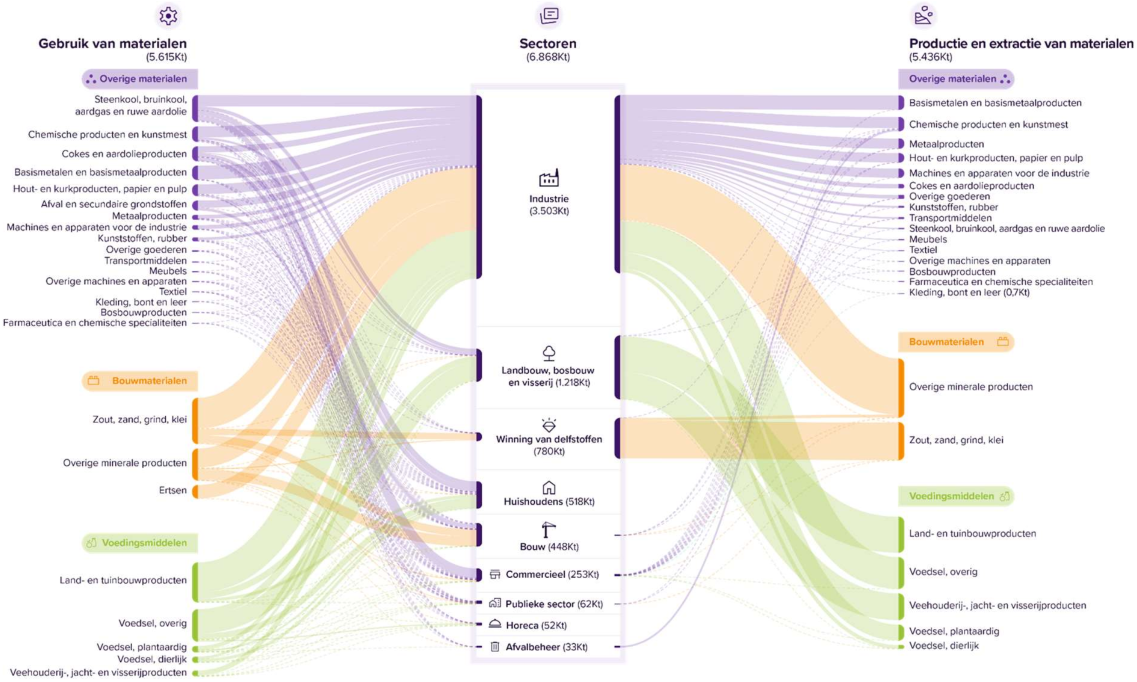

Figure 2. North-Limburg material flows

South Limburg has both the largest and the most industrially concentrated material economy in the province. Total material consumption amounts to approximately 13.9 Mt, while material production and extraction reach approximately 12.7 Mt (Figure 4). Industry dominates these flows, with chemical products and fertilizers playing a particularly prominent role, reflecting the concentration of chemical and industrial activities in the region.

Taken together, the three regions exhibit distinct profiles within Limburg's broader material economy: a more agriculture- and food-oriented profile in North Limburg, a concentration of mineral extraction and construction materials in Central Limburg, and a strong chemical-industrial profile in South Limburg. These differences underline the importance of region-specific approaches to accelerating the circular transition and developing targeted circular economy strategies.

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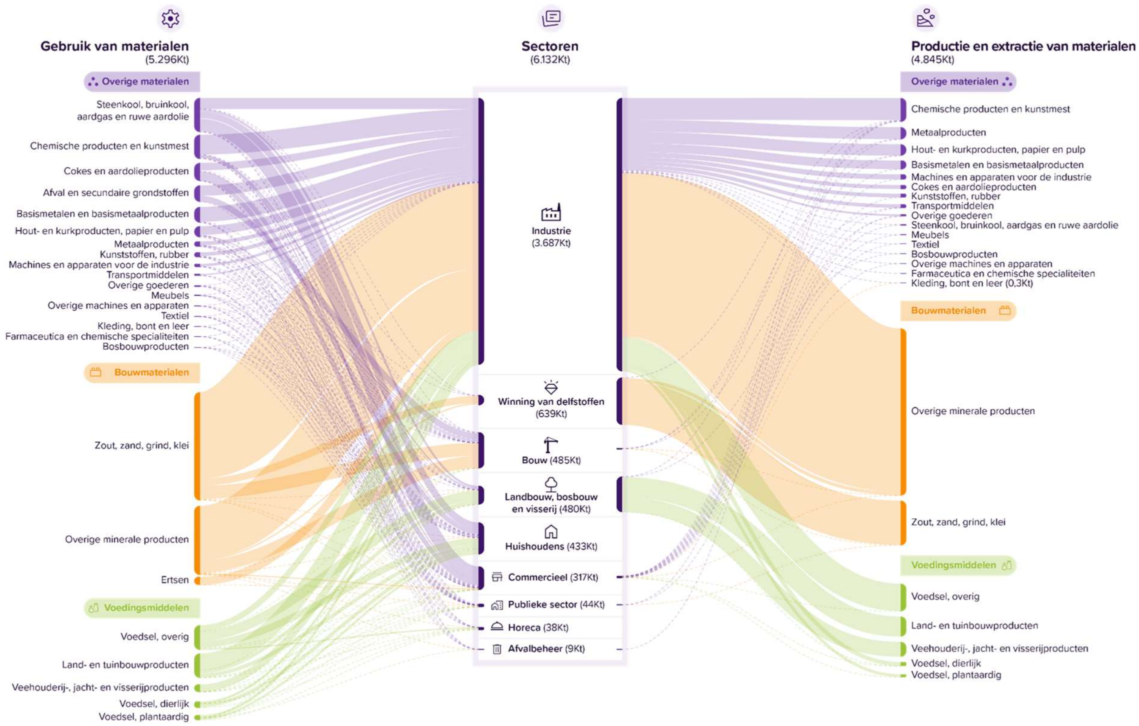

Figure 3. Middle-Limburg material flows

From a national perspective, Limburg occupies a middle position in terms of the overall volume of goods flows. In 2022, the province ranked fifth among all Dutch provinces in total goods throughput. [2] The province's material profile is more distinctive: chemicals, plastics, and rubber account for a relatively large share of material use in Limburg (20%). By contrast, agriculture represents the smallest share of material use of any Dutch province. Although North Limburg accounts for a significant proportion of Limburg's agricultural activity, its contribution remains relatively modest on a national scale.

Fossil fuels account for 15% of material use, well below the national average of 29%. This difference is partly explained by the strong influence of port provinces such as Zeeland, South Holland, and Groningen, where fossil fuels represent more than 40% of total material use. Compared with other inland provinces, Limburg's share is therefore broadly in line with the average.

[2] CBS study: De goederenstromen van de provincies 2015-2022.

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Between 2015 and 2022, goods consumption in Limburg increased by 9%, while regional material supply declined by 6%, contrasting with the national trend, where material supply increased over the same period.

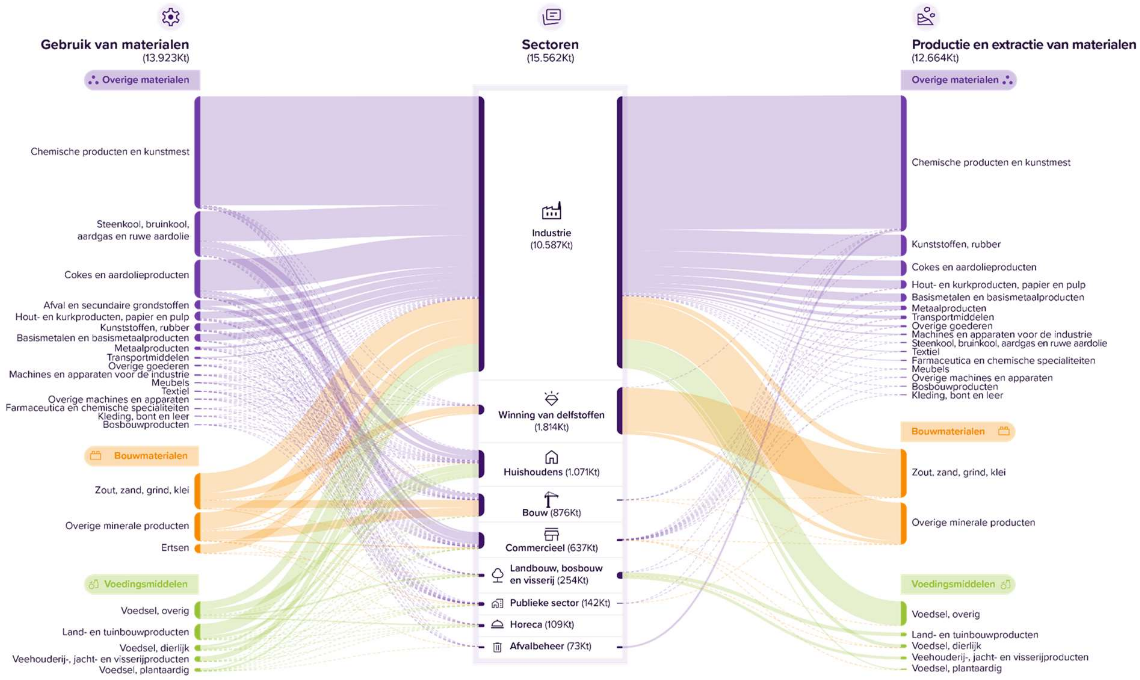

Figure 4. South-Limburg Material Flows

3.2 Waste Flows

At the provincial level, the analysis of registered waste streams (Figure 5) identifies approximately 3.88 Mt of waste. Mineral waste materials account for the largest share, with the construction sector, households, and the public sector generating the highest volumes. Other sectors, including industry, agriculture, mining, and hospitality, produce smaller and more diverse waste streams consisting of metals, animal and plant-based materials, chemical waste, wood, plastics and rubber, paper and cardboard, glass, and textiles.

The dominance of mineral waste reflects the significant role of construction and demolition activities within Limburg's economy. As a result, waste generation is highly concentrated in a limited number of high-volume material categories, while many other material streams occur in smaller quantities but often require more specialised collection, treatment, and recovery processes. This diversity highlights the importance of considering both the volume and composition of waste when identifying opportunities for circularity and resource recovery.

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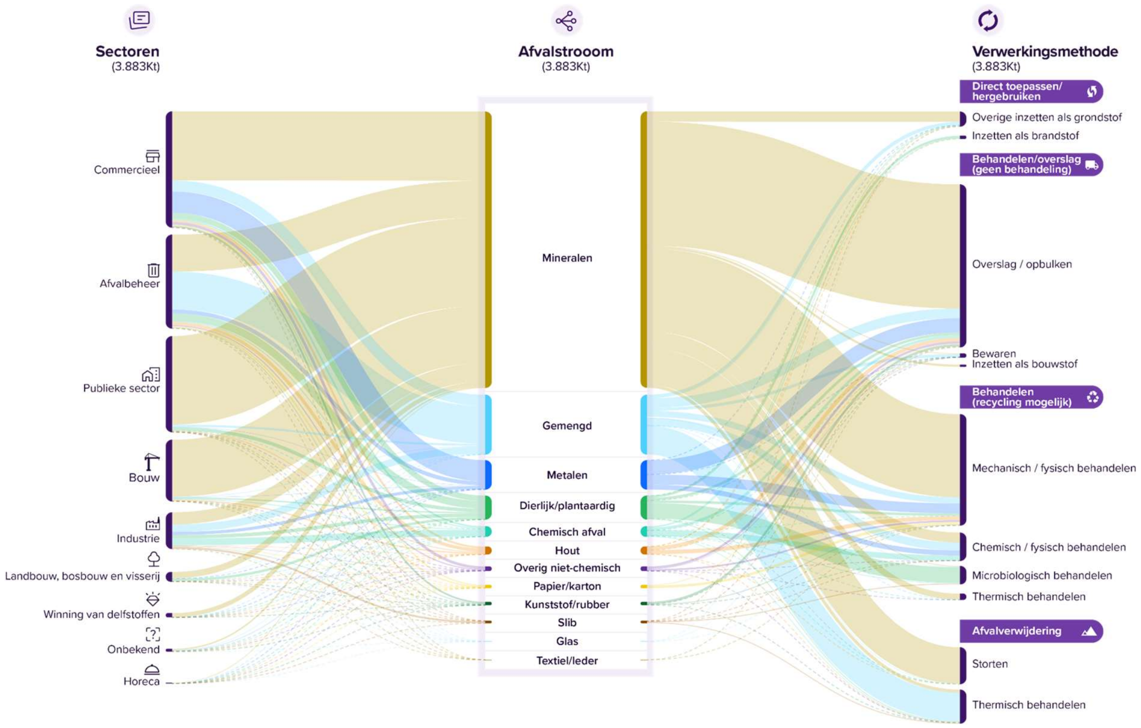

Figure 5. Waste flows

Waste treatment patterns in Limburg vary considerably across waste streams. Mineral waste plays a dominant role in both transport and storage, particularly in the form of contaminated soil and construction rubble, as well as in mechanical recycling, where concrete, stone, gypsum, and asphalt account for a large share of the processed volume. Other waste streams are distributed across chemical, microbiological, and thermal treatment methods, while smaller quantities are incinerated or landfilled. Household residual waste is significantly smaller in terms of mass than mineral and construction-related waste streams, but the majority is directed towards thermal treatment.

These treatment categories describe how waste is managed, but they do not in themselves provide a complete picture of circularity performance. Material that is registered as recycled does not necessarily return to the same application or function as a substitute for virgin resources. As a result, waste treatment data should be interpreted alongside information on material quality, value retention, and secondary material markets when assessing progress towards a circular economy.

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3.3 Environmental Impacts

The environmental impact assessment changes the relative importance of material categories when compared with their physical throughput. Mineral materials such as salt, sand, gravel, and clay account for a large share of total material mass, but play a less prominent role across the environmental indicators considered. In contrast, food- and biomass-related categories, including animal-based food products and agricultural commodities, become more significant when examining water consumption and land use. Chemical products and plastics, meanwhile, are particularly important contributors to greenhouse gas emissions.

These findings demonstrate that material volume alone is not a sufficient basis for prioritisation within the circular transition. Different material categories contribute to environmental pressures in different ways, meaning that strategies aimed at reducing material use, waste generation, carbon emissions, water consumption, or land occupation may require different points of intervention. Combining material flow and environmental impact perspectives therefore provides a more comprehensive basis for decision-making and policy development.

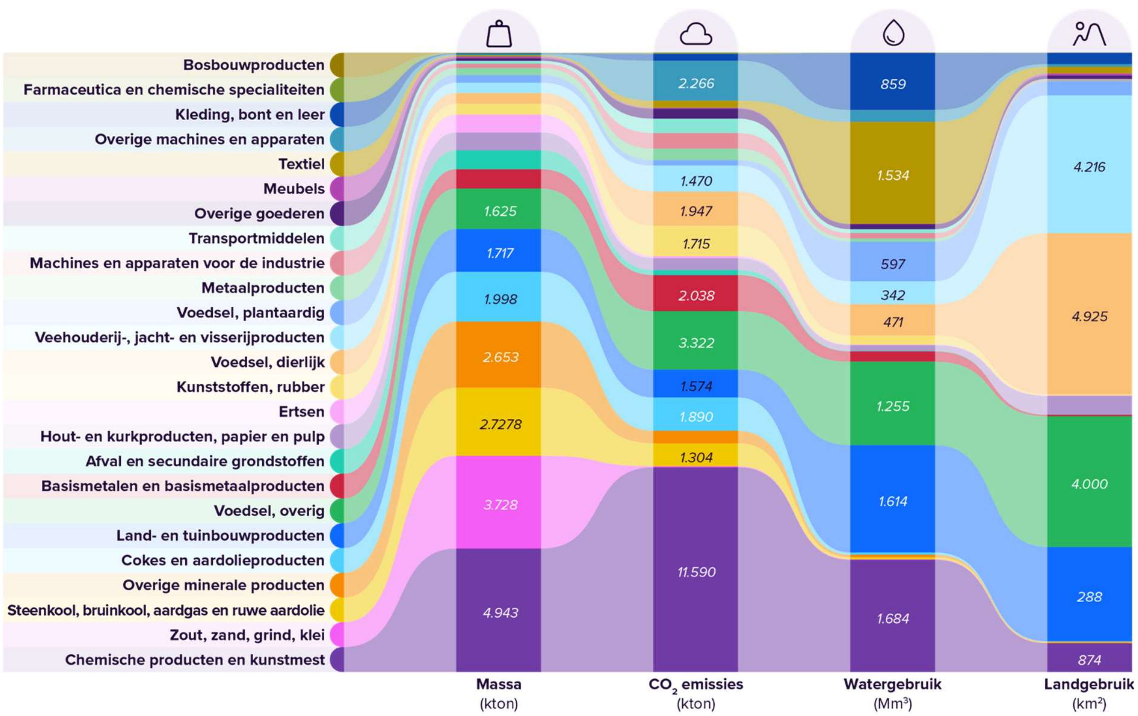

Figure 6. Impactanalysis

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3.3 Environmental Impacts

The findings demonstrate that different priority profiles emerge depending on the dimension under consideration. Mineral and construction materials dominate physical throughput and registered waste volumes, industrial and chemical materials play a prominent role in CO_2 emissions, while food- and biomass-related materials are particularly significant in terms of water consumption and land use. Prioritisation based solely on material mass would therefore risk overlooking smaller material flows that have substantial environmental impacts.

Taken together, material volumes, waste generation, and environmental pressures provide complementary perspectives on the circular economy challenge in Limburg. However, these findings remain primarily organised around materials and economic sectors, offering only limited insight into the societal functions that they collectively support. The following chapter therefore introduces a systems of provision perspective, linking material use and environmental pressures to the fulfilment of societal needs and exploring the implications for regional circular economy priorities.

4. A Systems of Provision Perspective on Regional Circular Economy Transitions

4.1 From Economic Sectors to Societal Needs

The material flow and environmental impact analyses provide a quantitative picture of resource use and the associated environmental pressures within the Limburg economy. A systems of provision perspective forms a crucial complement to this sector- and material-based analysis by relating these flows to the societal needs that generate demand for economic activity. This perspective brings together interconnected activities, actors, infrastructures, and institutions around functions such as housing, food, mobility, and healthcare, thereby offering an additional lens through which to understand the regional material economy. Within this framework, circularity contributes to the broader objective of meeting human needs while simultaneously reducing material demand and environmental pressures within planetary boundaries.

4.2 Translating Sectoral Data into Systems of Provision

To analyse the data from the perspective of societal needs, the sectoral dataset was reorganised. Following the classification used in the Circle Economy methodology[3], SBI sector codes were assigned to the societal need they primarily support. This results in seven systems of provision: housing, food, industrial goods, mobility, communication, healthcare and education, and other services.

This approach presents a fundamentally different picture from a traditional sectoral classification. For example, the housing system encompasses construction, construction materials, utilities, and related services, while the food system brings together agriculture, food processing, logistics, and retail activities. This quantitative classification is complemented by a qualitative analysis of each system of provision, highlighting key actors, innovation profiles, and connections to resilience and broad well-being within the region.

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In this report, we apply this approach to the food system in Limburg as an illustration of the insights that a systems of provision perspective can provide for strategic decision-making and policy development.

4.3 Material Use Across Different Systems of Provision

When material flows in Limburg are examined in terms of societal needs, resource use is found to be concentrated in three systems (Figure 7). Housing and industrial goods each account for approximately 37-38% of total material use, followed by food at 19%, while mobility, communication, healthcare and education, and other services represent considerably smaller shares.

This concentration reflects the material requirements associated with the interconnected activities that collectively fulfil societal functions, rather than the resource intensity of individual economic sectors in isolation.

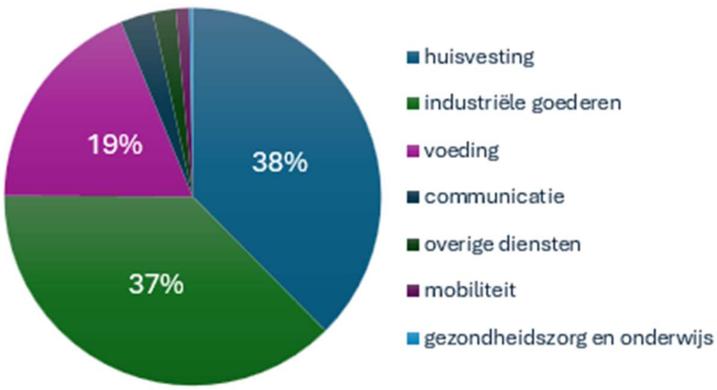

Figure 7. Material use per domain of provision

4.3 Material Use Across Different Systems of Provision

The relative importance of these systems also changes when environmental impacts are considered instead of the physical weight of material flows. Industrial goods account for the largest share of the carbon footprint, while food plays a particularly prominent role in water consumption and is the dominant system in terms of land use (Figure 8). Despite its large share of material use by weight, housing contributes relatively less to these forms of environmental impact.

The systems of provision perspective therefore brings the physical and environmental dimensions of provision together within a single analytical framework: the materials required to meet societal needs and the environmental consequences associated with those material inputs.

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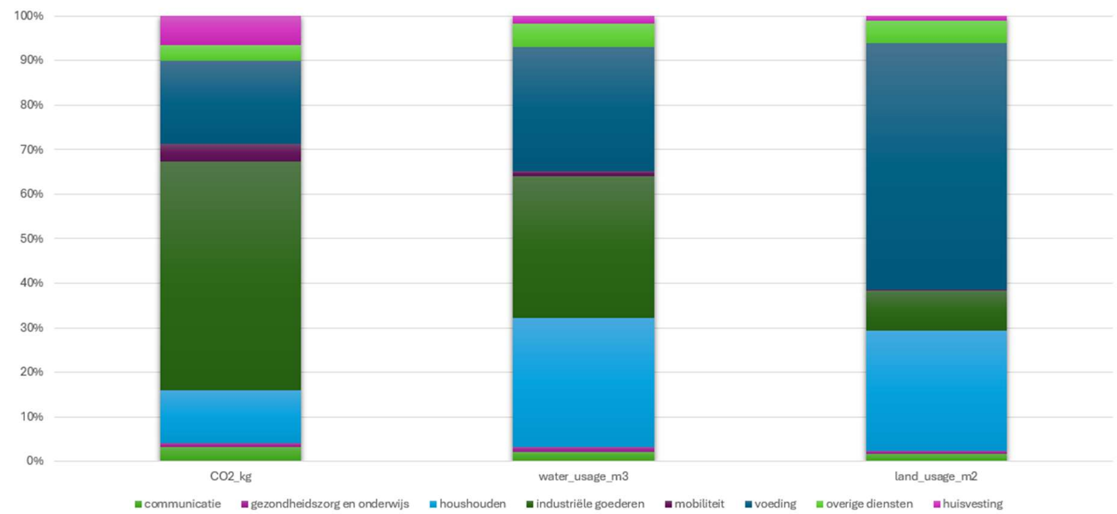

Figure 8. Impactcategories per domain of provision

4.4 Food Provision in Limburg: An Illustrative Example

Material Use and Environmental Pressures

The food system provides a useful illustration of applying a systems of provision perspective in Limburg. Food provision depends on an interconnected network that extends across primary production, processing, logistics, retail, hospitality, and household consumption, alongside the management and valorisation of residual streams. By considering these activities as a single system, it becomes possible to understand how circularity intersects with economic development, innovation, health, broad well-being, and resilience, and how interventions in one part of the system may create opportunities and trade-offs elsewhere. This perspective also demonstrates how systems thinking can inform regional circular economy priorities by shifting attention from individual materials and sectors to the functioning and long-term sustainability of the provision system as a whole.

Material Use and Environmental Pressures

Food is the third-largest system of provision in Limburg, accounting for approximately 19% of attributed material use by weight. Its environmental footprint is particularly significant: the food system accounts for a substantial share of water consumption and represents the

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largest contributor to land use among all systems of provision. At the same time, significant resource losses occur at multiple stages of the supply chain. For example, 39% of food waste is generated at the production stage, before products reach retailers or the hospitality sector.[1]

After food reaches households, approximately 129 kg of food per capita per year is wasted in the Netherlands. [2] As no region-specific data on household food waste are currently available for Limburg, national figures are used as an indicative benchmark. While actual levels in Limburg may differ, the available data do not allow for a reliable regional estimate. These losses highlight the need for strategies that reduce resource demand across the entire system by preventing food waste and creating higher-value applications for organic by-products and residual biomass.

[1] For the visualisation of import and export data the MFA analysis is combined with CBS study: ‘De goederenstromen van de provincies 2015-2022’. 2

[2] CBS-studie De goederenstromen van de provincies 2015-2022.

Economic Profile and Actor Landscape

The food provision system in Limburg generates an estimated €2.6 billion in gross value added and provides employment for approximately 35,000 people across agriculture, food processing, logistics, wholesale, retail, and related food services.[3] These activities are particularly concentrated in North Limburg and around Greenport Venlo, where production, processing, logistics, and cross-border trade form an interconnected regional cluster.

This economic structure is supported by a diverse network of public, private, knowledge, and civil society actors. Provincial and municipal governments, together with Waterschap Limburg, shape relevant spatial, environmental, and water management conditions. The LLTB and producer organisations represent primary producers, while businesses organise processing, trade, and distribution activities. Knowledge and innovation capacities are concentrated around Brightlands Campus Greenport Venlo and other regional research and educational institutions. Public health organisations, food banks, schools, and social welfare organisations provide connections between food provision and citizens where these links are not established directly through markets. Initiatives focused on short supply chains and producer-consumer relationships further strengthen the connection between production and consumption, creating opportunities for traceability, producer income, and value retention within Limburg.

[3] shiftLimburg, Food waste challenge (2023)

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Innovation Profile

Limburg's food innovation profile builds on these regional strengths, with particular attention to alternative proteins, healthy nutrition, the valorisation of by-products and organic residual streams, and the reduction of harvest losses. Together, these developments connect technological innovation with resource efficiency, circularity, and public health.

Brightlands Campus Greenport Venlo and LIOF play facilitating roles by connecting businesses, research organisations, and public authorities around these developments. Emerging applications in bio-based construction further broaden this innovation landscape by linking agriculture to other systems of provision. Fibre crops and other bio-based feedstocks provide renewable construction materials while simultaneously supporting agricultural diversification and new value chains. Initiatives such as Building Balance make these connections between agriculture, processing, and construction more tangible.

From a systems of provision perspective, innovation therefore extends beyond individual technologies to include new linkages between sectors and new ways of organising value chains. Regional distribution systems, producer cooperation, the valorisation and diversification of agricultural products, and alternative revenue models can all influence how resources and value circulate within and between systems of provision.

Broad Well-Being and Resilience

Food provision contributes to broad well-being through several interconnected dimensions, including access to food, public health, employment and regional value creation, environmental quality, and social inclusion. In Limburg, the ability to benefit from the food system is unevenly distributed. Approximately 14.5% of residents are at risk of poverty,[4] while regional well-being indicators point to inequalities in access to healthy food and related outcomes such as disease prevalence and life expectancy.[5]

Food provision therefore links circularity to broader issues of affordability and health. Efforts to reduce resource use and food waste can be considered alongside improving access to healthy food and ensuring a fair distribution of value and benefits throughout the regional food system. There is also a clear connection with climate change mitigation and adaptation.

Resilience adds a temporal dimension to this perspective and refers to the capacity of the system to continue providing sufficient, affordable, and healthy food under changing conditions and in the face of

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disruptions. Limburg combines substantial agricultural, processing, and logistics capacities with strong integration into international supply chains, while remaining dependent on external inputs such as animal feed (for example soy), fertilisers, energy, and labour. These interdependencies are further complicated by increasing disruptions associated with drought, heat, extreme precipitation, and water scarcity.

Under the right conditions, regional food chains, circular nutrient and material flows, and viable income models for farmers can strengthen resilience by retaining regional value, reducing selected external dependencies, and diversifying supply networks. Considering broad well-being and resilience alongside the circular transition ensures that circularity extends beyond resource efficiency alone. In this way, the transition can contribute to long-term societal well-being through improved health outcomes, food security, and supply reliability.

[4] CBS, SDG 12.3 Halve per capita global food waste in production and consumption (2022)

[5] CBS, Labor volume, output, and added value by region (2010 – 2023)

5. Conclusion

The findings show that Limburg's circular economy priorities differ depending on the material flows, environmental impacts, and regional profiles under consideration. Mineral and construction materials dominate physical throughput and waste generation, industrial and chemical materials play a prominent role in the carbon footprint, while food- and biomass-related materials are particularly important in terms of water consumption and land use. These patterns vary across North, Central, and South Limburg, underlining the importance of differentiated regional priorities that take into account both material volumes and environmental impacts.

A systems of provision perspective complements this analysis by linking resource use to the societal needs these resources support. The food system illustrates how circularity intersects with economic activity, innovation, broad well-being, and resilience, extending

the analysis beyond material-flow efficiency towards the long-term organisation and sustainability of systems of provision. Together, these perspectives provide a foundation for a regionally tailored circular transition that reduces material demand and environmental pressures while supporting resilient and socially valuable systems of provision.

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Appendix

1. Methodology

1.1 Material Use and Supply

Material use and material supply by economic activity are estimated by linking the regional economic structure from the LISA business register to national material intensities derived from the CBS Material Monitor. Each establishment in Limburg is assigned both a two-digit and a three-digit SBI industry classification. Material use and supply intensities, expressed in kilograms per employee, are subsequently linked to establishments based on their sector classification. The most detailed sector level available is used: where possible, coefficients at the three-digit SBI level are applied, while two-digit coefficients are used when more detailed information is unavailable.

For each establishment, the relevant material intensity is multiplied by the number of employees. Conceptually, an establishment operating in a sector with a given level of material use per employee is assigned an estimated material volume proportional to its employment size. These establishment-level estimates are subsequently aggregated by economic sector, material group, and flow direction (i.e. material use or material supply).

Household material flows are estimated separately because employment is not an appropriate scaling variable for household consumption. Instead, population figures for Limburg are combined with per capita material intensity coefficients. The resulting estimates represent the material use and material supply associated with the number of residents in the region.

Two categories are intentionally excluded from this part of the analysis. Fossil energy carriers, including natural gas, diesel, and petrol, are excluded because more up-to-date information is available through the Dutch Climate Monitor. Waste and recycling categories included in the Material Monitor are also excluded in order to avoid double counting, as waste is analysed separately using LMA registrations.

1.2 Environmental Impact Assessment

Environmental impacts are calculated for materials entering the economy (i.e. the material use side of the Material Flow Analysis) by multiplying estimated material quantities by the corresponding impact factors and converting units where necessary. The analysis covers three environmental dimensions: carbon footprint (kg CO_2-equivalent), water consumption (m^3), and agricultural land use (m^2).

The impact assessment is based on the same material flows identified through the MFA, but evaluates them using different environmental indicators. This means that every material category can be assessed both in terms of its physical volume and in terms of its associated carbon footprint, water consumption, and land use.

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This distinction is important because the volume of a material flow does not necessarily reflect its environmental significance. A relatively small material flow may generate substantial environmental pressures, while a much larger flow may have comparatively lower impacts per unit. The assessment therefore provides a more comprehensive perspective by distinguishing between materials that are important because of their physical scale and those that require attention because of their environmental impacts.

1.3 Waste Flows

Whereas material use and material supply are estimated using national intensity coefficients, the waste component of the analysis is constructed from individual waste registrations contained in the National Waste Registration System (LMA) database. Waste records are first geographically filtered to identify flows originating in Limburg, using either the registered origin location or the postcode of the waste processor. Records with European Waste Catalogue (EWC) codes beginning with 19, representing waste generated through waste treatment activities, are excluded to avoid double counting.

An additional methodological step is required to determine the economic origin of these waste flows. As LMA records do not contain SBI classifications, individual waste registrations are linked to establishments in the LISA register through a hierarchical matching procedure. The strongest available identifier, the Chamber of Commerce (KVK) registration number, is used first. Unmatched observations are subsequently compared using company-name matching with a fuzzy-matching threshold of 90%, followed by progressively more detailed combinations of postcode, house number, and other address characteristics. Both the registered origin address and the address of the waste processor are taken into account. For observations that remain unresolved, information retrieved through the KVK API is used to identify trade names, registration numbers, and, where necessary, SBI classifications. Records for which no reliable match can ultimately be established remain classified as unknown.

Following this matching procedure, individual waste observations are enriched with sector classifications and grouped according to waste treatment methods. The resulting waste dataset therefore links both the quantity and composition of registered waste to the sector from which it originates and the treatment route reported for that waste.

1.4 Harmonisation and Limitations

Once the three analyses have been completed, classifications are harmonised to enable consistent comparison across materials, sectors, and geographical areas. The final dataset can therefore be examined from several complementary perspectives: by material, to identify the largest physical flows; by sector, to determine which parts of the economy are associated with those flows; by COROP region, to reveal differences in material profiles within Limburg; by waste treatment route, to show how discarded materials are managed; and by environmental impact, to identify material inputs associated with the greatest environmental pressures. Together, these perspectives provide an integrated overview of the

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scale, distribution, and environmental significance of material flows within the province, as presented in Chapter 3.

The results should be interpreted in light of several methodological limitations.

First, material use and material supply are regional estimates rather than direct measurements. National sector-specific material intensities are applied to Limburg using employment and population statistics, assuming that activities within a given sector broadly follow national patterns of material use.

Second, the material flow and waste components are derived from different sources and methodologies. Material flows are largely modelled estimates, whereas waste flows are based on observed and registered LMA data.

Third, the allocation of waste to economic sectors depends on linking LMA registrations to LISA establishments. Although the hierarchical matching procedure based on KVK registration numbers, company names, and address information improves coverage, some registrations cannot be reliably linked and therefore remain classified as unknown.

Fourth, registered treatment routes describe how waste is managed but do not provide information on the quality of the resulting secondary materials. Classification as recycling does not necessarily imply high-value recovery or closed-loop recycling.

Finally, the environmental indicators represent estimated impacts associated with material use, calculated using impact factors, rather than direct measurements of environmental pressures occurring within Limburg itself.

These limitations do not prevent the MFA from providing a consistent regional reference framework, but they do define the level at which its findings should be interpreted: primarily as a means of identifying broad material patterns, sectoral and regional differences, and areas that may warrant further investigation.

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