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Inspire Policy Making with Territorial Evidence

CIRCTER SPIN-OFF //

# Luxembourg Case Study

Final Report // March 2021

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# Abbreviations

| | |
|---|---|
| B2B | Business-to-business |
| B2C | Business-to-consumer |
| C2C | Consumer-to-consumer |
| CBM | Circular Business Model |
| CE | Circular Economy |
| CRV | Critical Raw Material |
| DE | Domestic Extraction |
| DMC | Domestic Material Consumption |
| DMI | Domestic Material Input |
| EC | European Commission |
| ESPON | European Territorial Observatory Network |
| ESPON EGTC | ESPON European Grouping of Territorial Cooperation |
| EU | European Union |
| GDP | Gross Domestic Product |
| GVA | Gross Value Added |
| MFA | Material Flow Analysis |
| NACE | Nomenclature of Economic Activities |
| NUTS | Nomenclature of Territorial Units for Statistics |
| PPS | Purchasing Power Standards |
| PU | Potential Users |
| RMC | Raw Material Consumption |
| SME | Small and Medium enterprises |
| ToR | Terms of Reference |
| WEEE | Waste from Electrical and Electronic Equipment |

# Foreword by Claude Turmes
## - Minister for Spatial Planning of Luxembourg

The development of digital technologies allowing the rapid and free distribution of information has presented unprecedented opportunities for learning and understanding through the democratisation of knowledge, but it has also created enormous challenges. The spread of misinformation, the formation of epistemic bubbles and increasing polarization are, for instance, undermining the trust of citizens in public authorities. It is, therefore, the duty of policymakers to work to regain that trust by making – what the OECD calls – “better policies for better lives”. In this sense, the contribution of scientific evidence to create better policies has never been more relevant.

ESPON, an EU-funded interregional programme of European Territorial Cooperation that we are hosting here in Luxembourg, has supported evidence-based policymaking since 2002 by providing European policymakers at all levels with pan-European, comparable, systematic and reliable territorial evidence. Through its territorial evidence, ESPON can support policymakers in all stages of the policymaking process: Policy briefs and working papers help to identify territorial trends and set the policy agenda; handbooks, targeted analyses and territorial data inform the design of policies; in-depth case studies offer lessons on how to implement policies; online tools facilitate monitoring; and applied research projects contribute to the evaluation of policies.

ESPON evidence can help to increase institutional capacity and provides policymakers with the necessary tools to design place-based and territorially-sensitive policies that take into account the capital, needs and challenges of a given territory and its inhabitants.

There is a tradition of using ESPON evidence to inform policymaking in Luxembourg. So far, this has largely been limited to spatial planning and territorial cooperation. However, given the importance of the circular economy and its territorial consequences, the decision to realise a spin-off for ESPON’s CIRCTER (Circular Economy and Territorial Consequences) project with a case study on Luxembourg allows ESPON to have also an impact on sectoral policy in Luxembourg.

In February 2021, the Luxembourg government presented its “National Circular Economy Strategy”, which aims at aligning promising top-down and bottom-up initiatives and at bundling the experiences of the last few years since the publication of the first study on the circular economy in Luxembourg in 2014. Various sectors of the Luxembourgish economy, such as the construction sector, are very resource-intensive and heavily dependent on imports. Overall, Luxembourg’s environmental footprint is one of the highest worldwide. The National Circular Economy Strategy identifies proven regulatory, financial and information management methods and tools for boosting circular initiatives, and proposes a methodology for using them in a number of key economic sectors, thus fostering a smarter and more responsible management of resource stocks and flows.

The results of ESPON’s CIRCTER spin-off for Luxembourg come at the right moment, as they provide valuable data and information for setting objectives and drafting roadmaps for implementing circular economy principles in key economic sectors. First, the territorial analysis allows for the benchmarking of local and national efforts against other regions in Europe and designing tailor-made recommendations. The CIRCTER results position Luxembourg as one of the cutting-edge European regions in terms of circular business models already installed in the country. On the other hand, the analysis highlights very different circularity performance scores across municipalities, thereby confirming the need for a coherent governance and strong institutional cooperation along entire value chains, as identified in the National Circular Economy Strategy. Other important insights stem from the review of Luxembourg’s metabolism, based on aggregated material flows. The economic dependency on the import of large quantities of critical raw materials asks for a more accurate assessment of material stocks and flows as well as innovative approaches to capture the value in existing materials stocks, such as urban mining.

This spin-off is also an opportunity for the CIRCTER research team to apply the project’s methodology and tailor the project’s policy recommendations to an almost unique territorial context characterised by a high degree of cross-border integration in the heart of Europe. After all, more than 200.000 commuters come every day from the neighbouring countries of Belgium, France and Germany to Luxembourg for work, shopping and leisure. This also gives the research team working on this spin-off the chance to consider how to address and potentially capitalise on the cross-border dimension of the circular economy.

Lastly, I want to thank the research team for their dedication and the ESPON EGTC for their support throughout the process. I sincerely hope that this spin-off does not only benefit policymakers in Luxembourg, but supports the efforts across Europe to promote a circular economy that reflects the territory in which it is embedded for the benefit of all.

Claude Turmes,
Minister for Spatial Planning of Luxembourg

# 1 Introduction

## 1.1 Background

The transition to a more circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible and the generation of waste minimised, is an essential contribution to the European efforts to develop a sustainable, low carbon, resource efficiency and competitive economy. The transition towards a circular economy is the opportunity to transform our economy, create jobs and generate new and sustainable competitive advantages in Europe.

Monitoring and analysing material and waste flows is critical to establish whether existing actions and policy measures are beneficial to the objective of the circular economy, and to assess if Europe is on the right track towards a circular resource-efficient economy. In December 2015, the European Commission published an EU Action Plan for the Circular Economy followed by, two years later, a framework to monitor progress towards the circular economy. The EC monitoring framework consists of 10 indicators, some of them with sub-indicators, addressing a whole range of aspects related to the circular economy, including material consumption, waste management, secondary material uses and competitiveness and innovation around CE businesses.

In parallel, the CIRCTER project made significant progresses in the identification of the potential territorial implications of a circular economy at subnational levels. The project took a special focus on a series of territorial factors, including land-based sources, agglomeration economies, accessibility conditions, knowledge and technology-based enablers, governance and institutional contexts, which ultimately affect the distribution and manifestation of circular economies at subnational levels. This territorial perspective was found to be critical not only to address the likely territorial consequences stemming from circular economy transitions, but also to identify the circular economy drivers and bottlenecks that characterise specific local contexts. Considering that the existing data on material consumption and waste generation is almost exclusively available at national level, the CIRCTER project produced regional estimates (at NUTS-2 level) for the main material consumption and waste generation and treatment indicators available from Eurostat. In addition, the CIRCTER project developed a sectoral perspective of circular economy. This differentiates between the demand-side and supply-side of circular product and/or services. The demand-side refers to the industries that adopt or rather demand new circular business processes, products and technologies that drive their uptake. Likewise, the supply-side is defined as the provision of materials, technologies and services for a circular economy. Thanks to this sectoral taxonomy of circular economy activities, the CIRCTER project produced regional estimates concerning the economic implications, in terms of employment and turnover, of the transition towards circular configurations.

More recently, the Annual Work Plan 2020 of the ESPON EGTC expressed its interest in implementing additional case studies as spin-offs of ongoing or closed research. For the CIRCTER project the MC agreed to implement additional case studies for the countries Luxembourg, Norway, Switzerland and Liechtenstein with the aim of increasing the national, regional and local relevance and application of CIRCTER's evidence in policy processes and developments at different scales. This report will focus on the **Grand Duchy of Luxembourg**, which, at the moment, is developing its national Circular Economy Strategy. In this respect, CIRCTER's evidence might provide further critical insights for the internal on-going policy processes carried out by the Ministry of Energy and Spatial Planning, , in collaboration with the Ministry of the Environment, Climate and Sustainable Development, Ministry of Economy and Ministry of Finance towards a comprehensive and inclusive strategy.

## 1.2 The Grand Duchy of Luxembourg

The very specific physical aspects of the Grand Duchy of Luxembourg (hereafter Luxembourg) coupled with its strategic geographical position make of this country a unique case in the European panorama. First of all, Luxembourg is the smallest European country in terms of surface area. Even when compared with European NUTS 2 regions, it figures among the smallest regions. The reduced availability of land constrained the direct use of natural resources. Indeed, Luxembourg exhibits a very limited share of domestically extracted raw materials, which are limited to biomass (crop residues and wood) and non-metallic materials (sand and gravel). In 2018, the extracted materials only represented the 9% of total material processed by

Luxembourg economy, the remaining 90% were imported from foreign countries. The lack of natural, locally available, resources strongly affected the structure of the Luxembourgish economy, which during the last decades went increasingly specialising in the service sector.

On the other hand, the strategic location in the centre of Europe, the moderate size of Luxembourg and the very developed transport infrastructure in place make of Luxembourg the most common destination for cross-border commuters in the EU (among NUTS level 2 regions). According with figures recorded in 2015, 171,100 cross-border commuters cross the Luxembourg border daily, of which 85,100 have their residence in France, 42,600 in Belgium and 42,600 in Germany. The number of cross-border workers is equivalent to 30% of the resident population and approximately the 42% of the total workforce in Luxembourg . Compared with 2010, the number of cross-border workers in Luxembourg increased by 11.2% in 2018 (PNGD, 2018).

These territorial dynamics must be taken into account when analysing material and waste statistics as they explain why Luxembourg scores relatively low when analysing CIRCTER indicators per capita, and, by contrary, very high when relating absolute values to GDP value. In fact, cross-border commuters work and consume in Luxembourg during the day and, therefore, also consume material and produce waste. However, according to the general rules applicable to statistics, they are not taken into account in the calculation of the specific quantities of the various material and waste streams. In addition, a large number of foreign service providers are present on Luxembourg territory to carry out their craft or industrial activities. These dynamics inflate material and waste statistics, above all when measured at per capita levels. Hence, “intensity indicators” such as material and waste intensity (i.e. KG/Euro), which relate the amount of material/waste consumed/generated to the unit of economic value generated, might represent a better indicator to measure the level of resource efficiency characterising Luxembourg.

In this sense, Luxembourg stands on the European frontier of resource-efficient regions, as either waste generated and material required to produce one Euro is among the lowest across European regions. This is, in part, favoured by the economic structure of Luxembourg. In fact, as a consequence of material intensive activities outsourcing, Luxembourg went increasingly specialising in knowledge-intensive activities such as the financial sector and end-of-pipe manufacturing activities having much higher added value compared to raw material extraction and initial processing. Notwithstanding, the Luxembourg performance remains above similar service-based regions, confirming the well doing of the country in terms of resource efficiency.

## 1.3 Structure of the report

The report is organised as follows. After this introduction, Chapter 2 provides a broad overview of CIRCTER estimates focusing on a selected set of indicators spanning from material consumption and waste generation to economic measures. The objective of this chapter is to position the situation in Luxembourg in the broader European context, identifying the key aspects that differentiate Luxembourg from the rest of the European regions.

Once defined the broader picture, Chapter 3 focusses specifically on Luxembourg metabolism, providing historical trends for material and waste patterns with higher granularity. Therefore, volumes and types of material/waste entering the Luxembourg country are analysed, along with the use/treatment that the country is making of them. This analysis relied predominantly on EUROSTAT and STATEC data.

Basing on the evidence generated in previous chapters, Chapter 4 elaborates on the Luxembourg territorial implications for transitioning towards a circular economy configuration. To this aim, the taxonomy of territorial factors generated in CIRCTER is employed to discern specific lessons and/or input towards a comprehensive circular economy strategy.

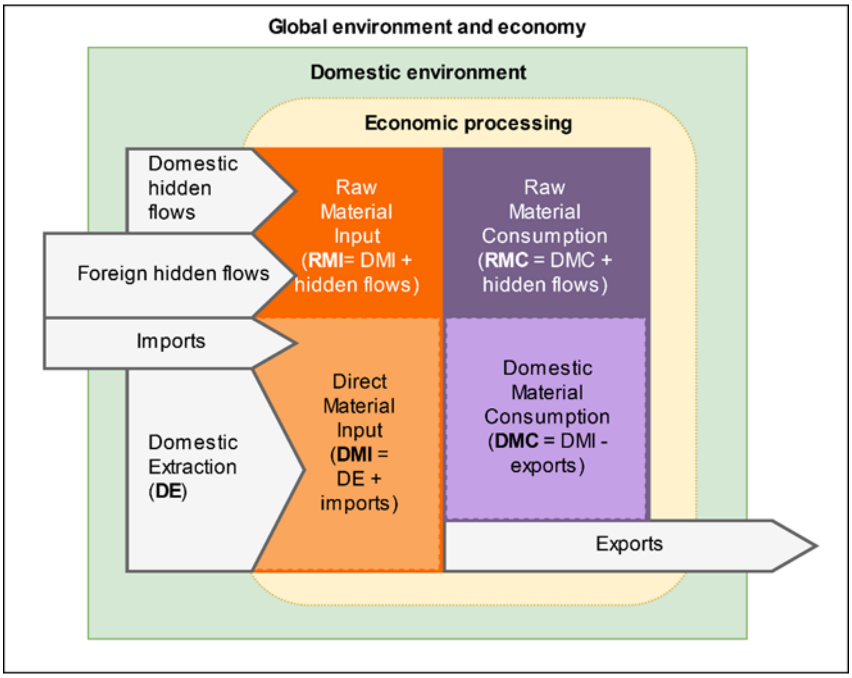
Finally, Chapter 5 concludes the report by delivering CIRCTER key messages adapted to Luxembourg context along with new lessons produced by the work done.

# 2 An overview from CIRCTER statistics

## 2.1 Material consumption patterns

Progress towards a circular economy should ultimately lead to a significant reduction on the total amount of primary raw material that are extracted from the environment. For this perspective raw material consumption (RMC) would be the ideal indicator. RMC represents the world-wide amount of primary raw materials directly and indirectly used by an economy (Wiedmann et al., 2015). Unfortunately, estimates of RMC are only available at the aggregated EU economy and for few countries. Therefore, the headline indicator available from Eurostat, and also employed in CIRCTER, to track material consumption is Domestic Material Consumption (DMC). DMC is calculated by means of simplified mass balances. This implies that the indicator only accounts for the actual mass of imported and exported goods (either intermediate or end products) when crossing the international boundaries. Remarkably, the resources that were used upstream to produce imported goods are not considered in the calculation of the DMC. These neglected materials are commonly known as *hidden flows*. Nonetheless, considering that the development over time of DMC and RMC is very similar across European countries, the use of DMC is generally accepted as good proxy for RMC. Similarly, an alternative indicator for material consumption is Direct Material Input (DMI), which sums the domestic extractions plus imports. However, because it does not balance out the materials extracted in one country and then imported by another one, the use of DMI would lead to double counting in the European aggregates. For these reasons DMC remains the most popular indicators measuring material consumption for a domestic economy. Figure 2-1 provides a graphic overview of economic-wide material flow indicators and their relationships.

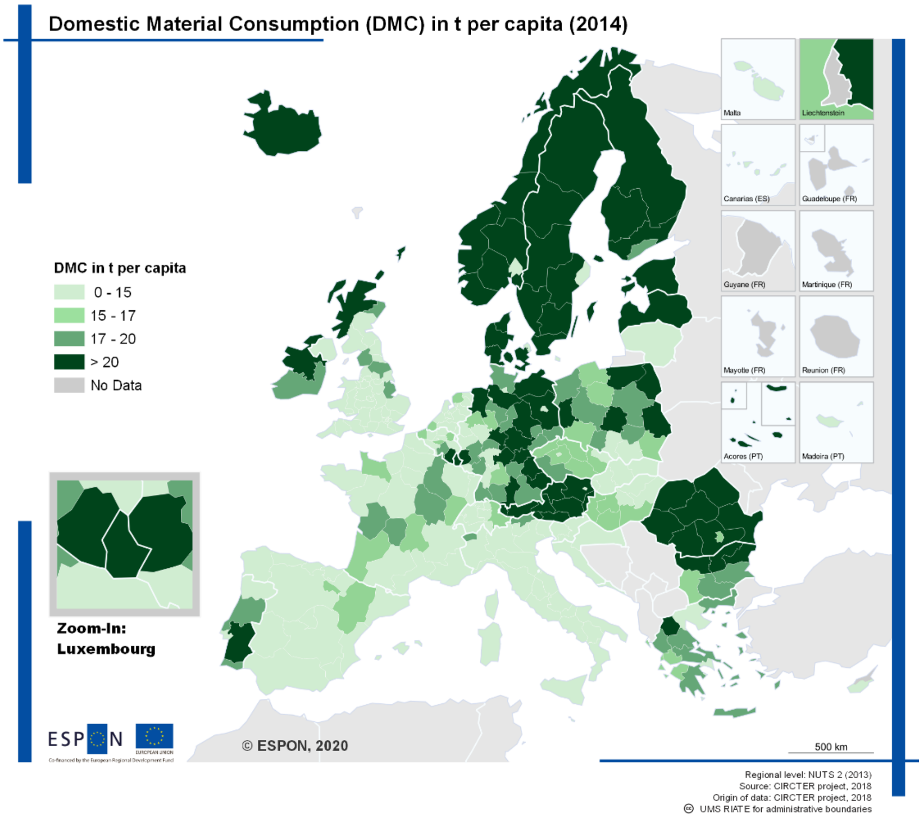
**Figure 2-1: Simplified overview of material flow indicators**



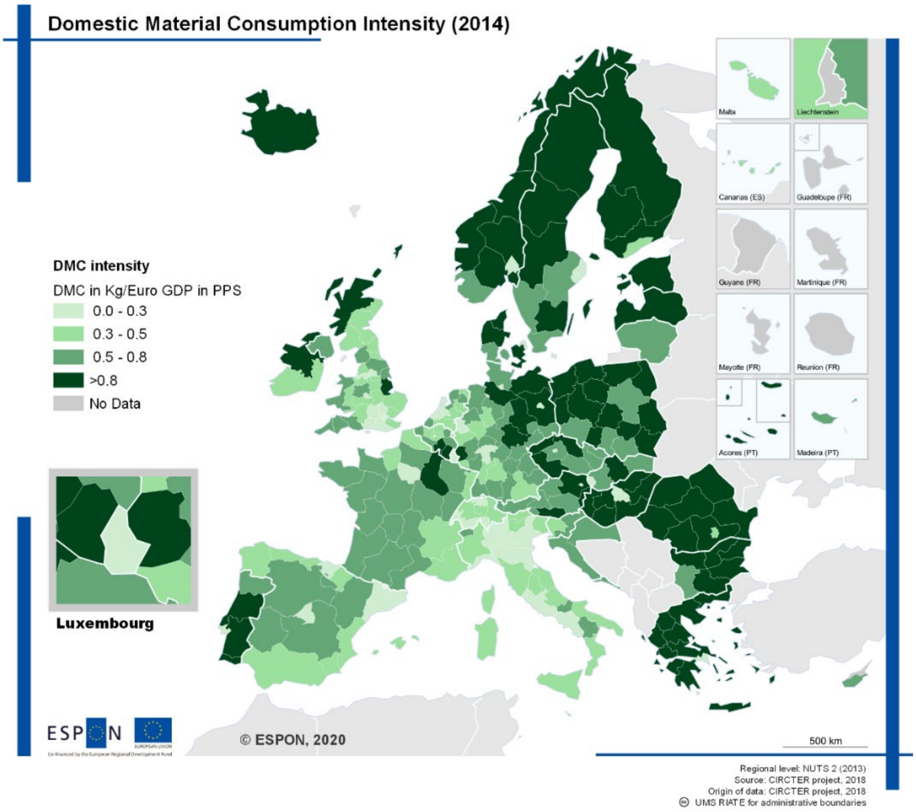

Source: CIRCTER project 2019.

Absolute values of DMC are generally very respondent to the size of a specific territory. Bigger economies and/or very populated regions will process and consume inevitably larger amounts of materials to meet respective human needs of domestic areas. As a consequence, absolute values say relatively little about the qualitative prospect of a socioeconomic systems characterising a territory. Therefore, DMC is generally expressed in terms of DMC per capita and DMC intensity. The first measures the amount of material consumed per inhabitant, while the latter measures the amount of material consumed to produce a unit of economic output. Map 2-1 and Map 2-2 show DMC per capita and DMC intensity, respectively.

## Map 2-1: Domestic Material Consumption (DMC) per capita (2014)

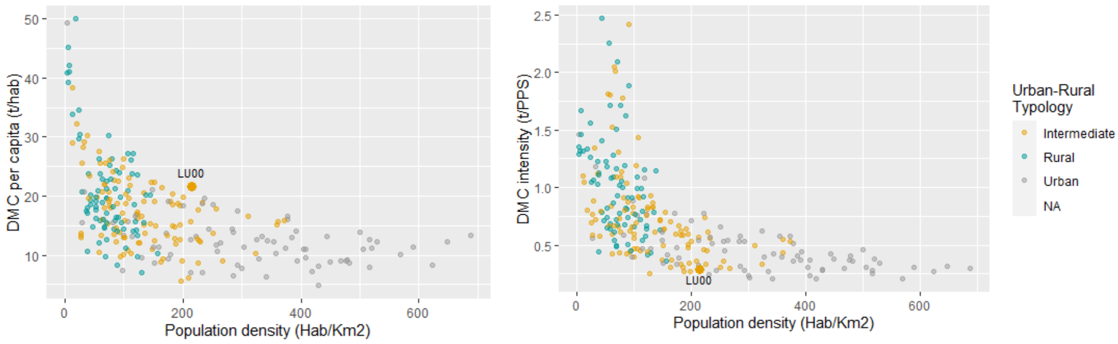



## Map 2-2: Material Intensity, measured as Domestic Material Consumption (DMC) in kg/Euro GDP in PPS (2014)



Despite European regions show, to greater extent, similar patterns across the two indicators, with south-western Europe and above all capital regions having better performance, Luxembourg represents an exception. In fact, when focusing on material consumption per inhabitant, Luxembourg figures in the lower rank, i.e. it is among the European regions consuming the largest amount of materials per capita (~>20 t/cap). However, when relating the DMC indicator to the economic output generated, Luxembourg is among the best performing European regions with 0.29 kg/Euro. This pattern is further highlighted when analysing DMC figures considering the urban-rural taxonomy based on the TERCET typologies[1]. Figure 2-2 compares DMC per capita and DMC intensity for urban, intermediate and rural regions. Luxembourg, which is considered an intermediate region, exhibits material consumption levels rather similar to rural areas when measured per capita. Conversely, it presents much closer figures to urban areas when considering DMC intensity.

## Figure 2-2: DMC per capita vs DMC intensity scatterplots (2014)

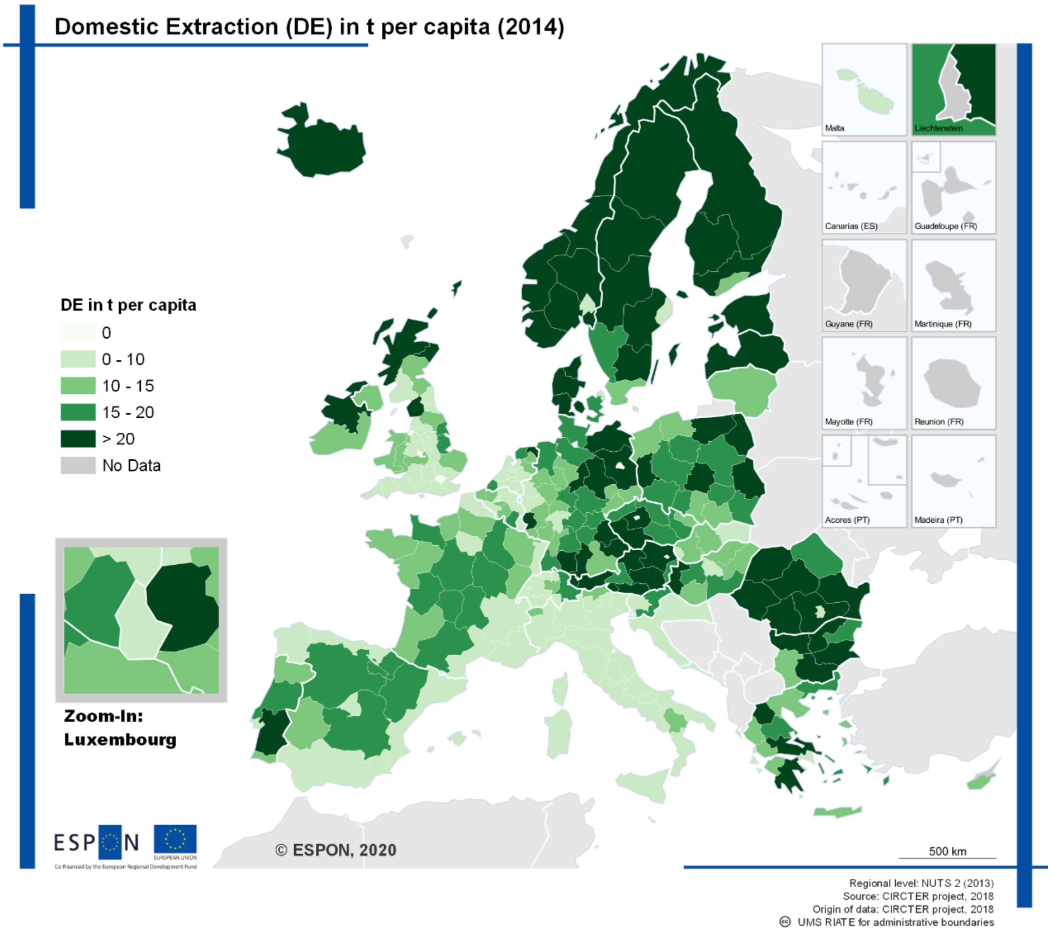



Source: own elaboration based on CIRCTER data

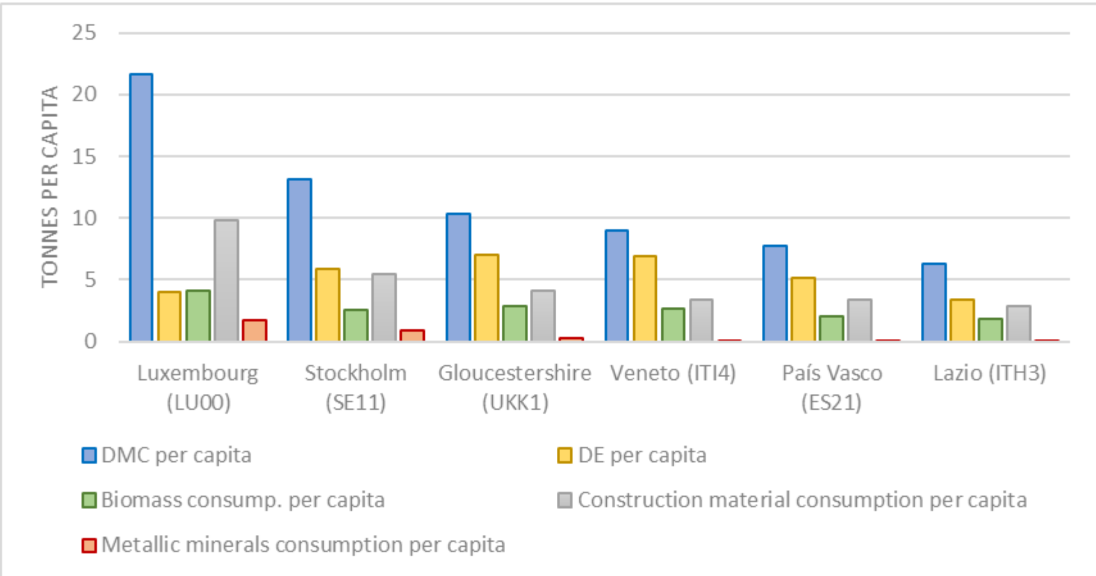
In general, higher DMC per capita values reflect an economy more tied to the exploitation of local natural resources. In fact, due to the limitation of DMC indicator, which only considers the final weight of traded good, regions conducting material-intensive activities such as mining, forestry and/or manufacturing are generally worse off compared to those regions which import already finite or semi-finite goods. However, according to Map 2-3, which shows the natural resources extracted domestically, Luxembourg represents, once again, an exception to the average European patterns, being its domestic extraction among the lowest figures observed across European regions (4.02 t/cap). Figure 2-3 offers a complementary perspective on Luxembourg's unique metabolism by comparing DMC, DE, biomass consumption, construction material consumption and metallic mineral consumption for a group of European regions having similar domestic extraction levels, along with similar socio-economics characteristics (i.e. GDP per capita and population density). The DMC of Luxembourg is regularly more than double (excluding Stockholm) of the other regions, while its extraction is among the lowest. This is mainly due to the use of construction materials (still more than double that in other regions) and metallic materials which, although on a smaller scale, are considerably higher. The reason Luxembourg has much higher material consumption levels than resource extraction is due to the huge imports the region has in terms of construction and metal ores. These material flows – i.e. imports – have not been analysed in the CIRCTER project, but a detailed review is presented in Chapter 3.

[1] The TERCET initiative integrates the urban-rural taxonomy across administrative units at NUTS 3 level (European Commission, 2016). In CIRCTER project this classification was upscaled to the NUTS 2 level in order to be applicable.

### Map 2-3: Domestic Extraction in tonnes per capita (2014)



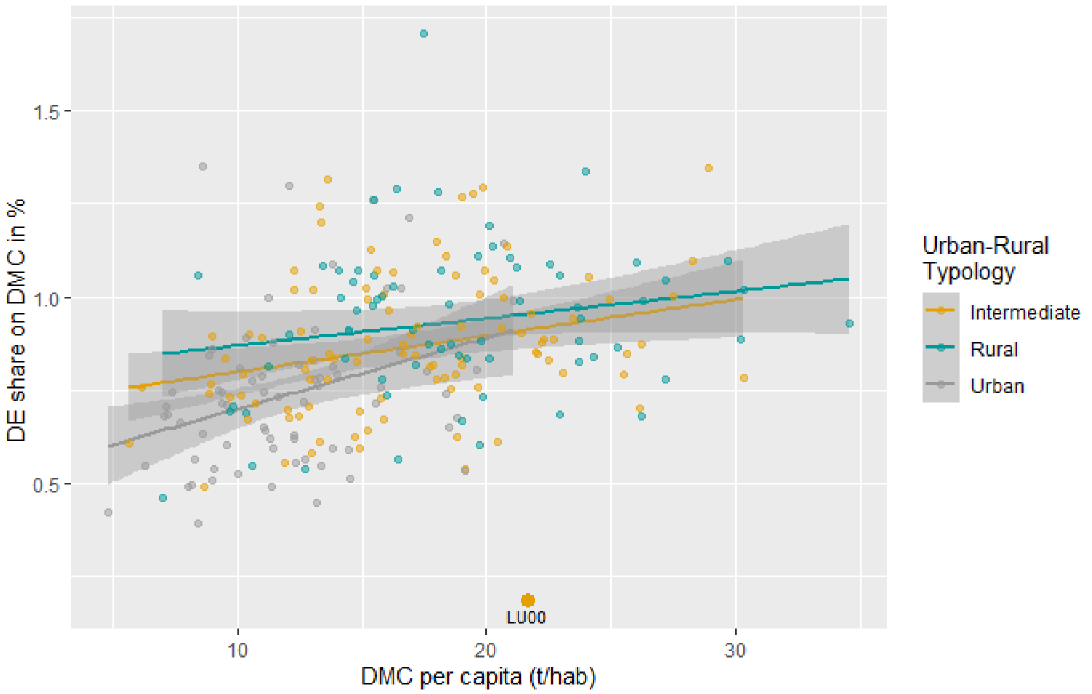

### Figure 2-3: DMC, DE and specific material consumption levels: comparison between a selected sample of European regions (2014)




Source: own elaboration based on CIRCTER data.

Figure 2-4 shows the relationship between DE share of DMC and DMC per capita. In general, we can appreciate a linear relationship, with a very similar pace across the territorial typologies, between the reliance of an economy on local natural resources and its overall consumption of material. Increasing resilience on local resource extraction translates, on average, in higher DMC per capita. Areas featuring a DE share over 100% DMC are generally exporting regions, which extract and exploit natural resource for foreign markets. Conversely, those areas having very small DE shares reflect importing regions. These latter generally undergo very limited availability of local natural resources, hence relying mostly on imports from other areas. Domestic extraction in Luxembourg accounts for only 18% of the total material consumed by the domestic economy in 2014. According to CIRCTER results, this represents the lowest figure recorded across European regions[2].

## Figure 2-4: DE share of DMC plotted against DMC per capita




Source: own elaboration based on CIRCTER data

Summarising, the material patterns of Luxembourg represent an exceptional case compared to average patterns observed across European regions. On one hand, the limited availability of land limits the direct exploitation of natural resource. This is commonly observed for similar reduced spatial unit such as Malta and or very agglomerated areas such as Ile de France, Madrid and/or Brussels. However, contrarily to these regions, Luxembourg presents very high levels of DMC per capita, which are generally observed in regions relying on primary and secondary sectors. Finally, the indicator of DMC intensity represents a further peculiarity as it places Luxembourg among the regions that consume less material to produce a unit of economic production.

These socio-metabolic patterns are partially explained by the huge flow of cross-border commuters who cross the border every day to work in the relatively more attractive Luxembourg market. Indeed, Luxembourg is the European region with the highest proportion of its workforce commuting from neighbouring regions.

[2] Excluding the metropolitan regions of Wien, Bruxelles, Praha, Berlin, Bremen, Hamburg, Merseyside and Inner London. Due to the reduced geographical extension of these cities and their very high urban densification, DE for these regions was set manually to zero.

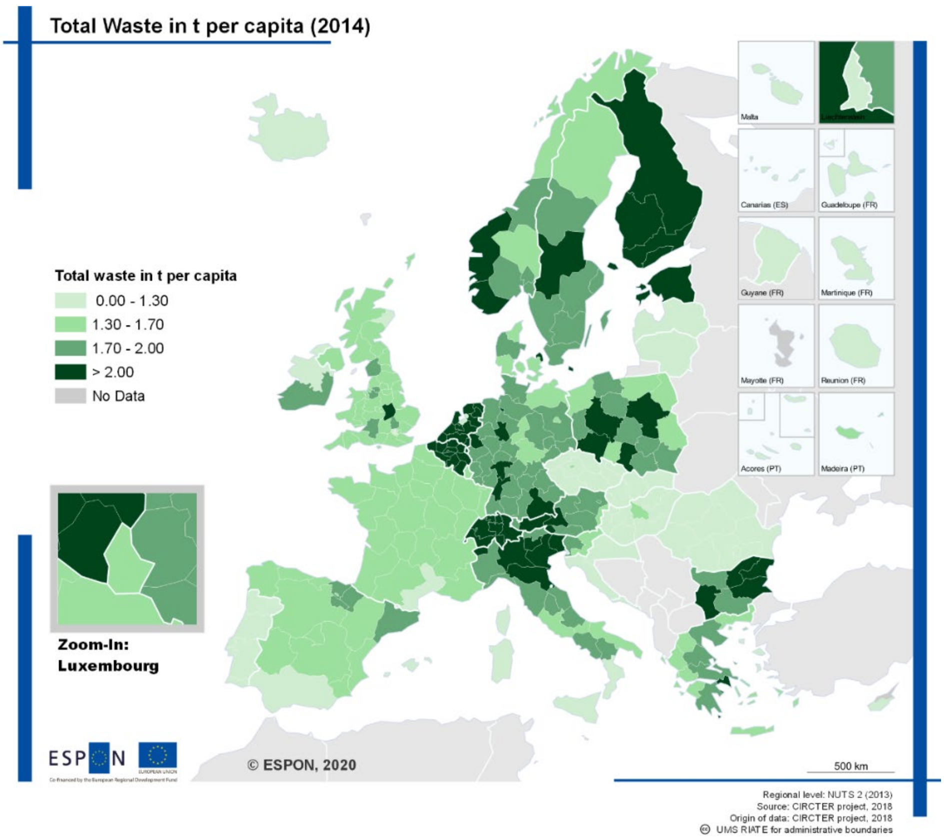
Despite this workforce does not reside in Luxembourg territory, it contributes to generate GDP, and, necessarily, it also influences the overall consumption of resources. Similarly, another important factor explaining the stark difference between the three indicators is constituted by the economic structure of Luxembourg and the types of flows which enter and exit the country. These are analysed in detail in chapter 3.

## 2.2 Waste generation and treatment

As highlighted in CIRCTER project, waste data comparability across countries and also within individual countries is somehow hampered by (1) the type of accounting methods employed by the countries, including surveys, administrative procedures and statistical estimations, and (2) the scope interpretation of, inter alia, municipal waste, secondary waste and recycling operations, which not always are the same between countries. As a result, it may be the case that the differences between countries in waste statistics respond much more to these outlined shortcomings, than to the actual quality of waste management infrastructure in place. A higher level of mindfulness is therefore required when comparing waste indicators between regions in different countries.

Map 2-4 shows the total waste (excluding major mineral waste)[3] per capita in 2014. Luxembourg figures in the medium rank with 1.6 t/cap waste generated, which is also the European median. However, it should be noted that, in some cases, the geographical distribution of waste generation is very aligned with national borders (e.g. France, Portugal, Romania etc.). This is likely due, as argued above, to existing differences in waste accounting and scope interpretation so that comparison between regions belonging to different countries might be not very robust.

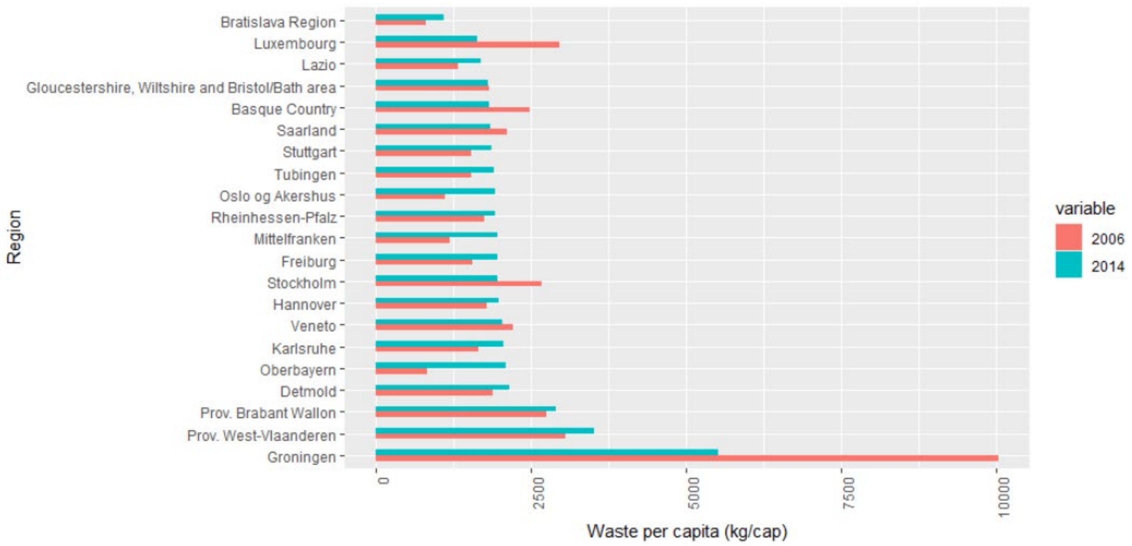
### Map 2-4: Total Waste (excluding major mineral waste) in tons per capita




[3] Major mineral wastes are excluded because otherwise "dilute" the amount of other waste categories

Since the generation of waste depends, to a greater extent, on the urban configuration of territories and the quality of infrastructure in place, it might be more sounding to compare the waste generated in Luxembourg with the performance of regions presenting similar socioeconomic facets. In this respect, Figure 2-5 shows waste generation for a selected sample of regions having GDP per capita between 30.000 and 80.000 PPS Euro per capita and population density between 200 and 400 inhabitants per square kilometres. Waste generation per capita in Luxembourg in 2014 is among the lowest figures within the representative regional sample. In addition, it should be considered that the indicator of waste per capita suffers from the same limitations of DMC per capita. In other words, it does not consider the commuters who operate – and generate waste – in Luxembourg but reside in neighbouring regions.

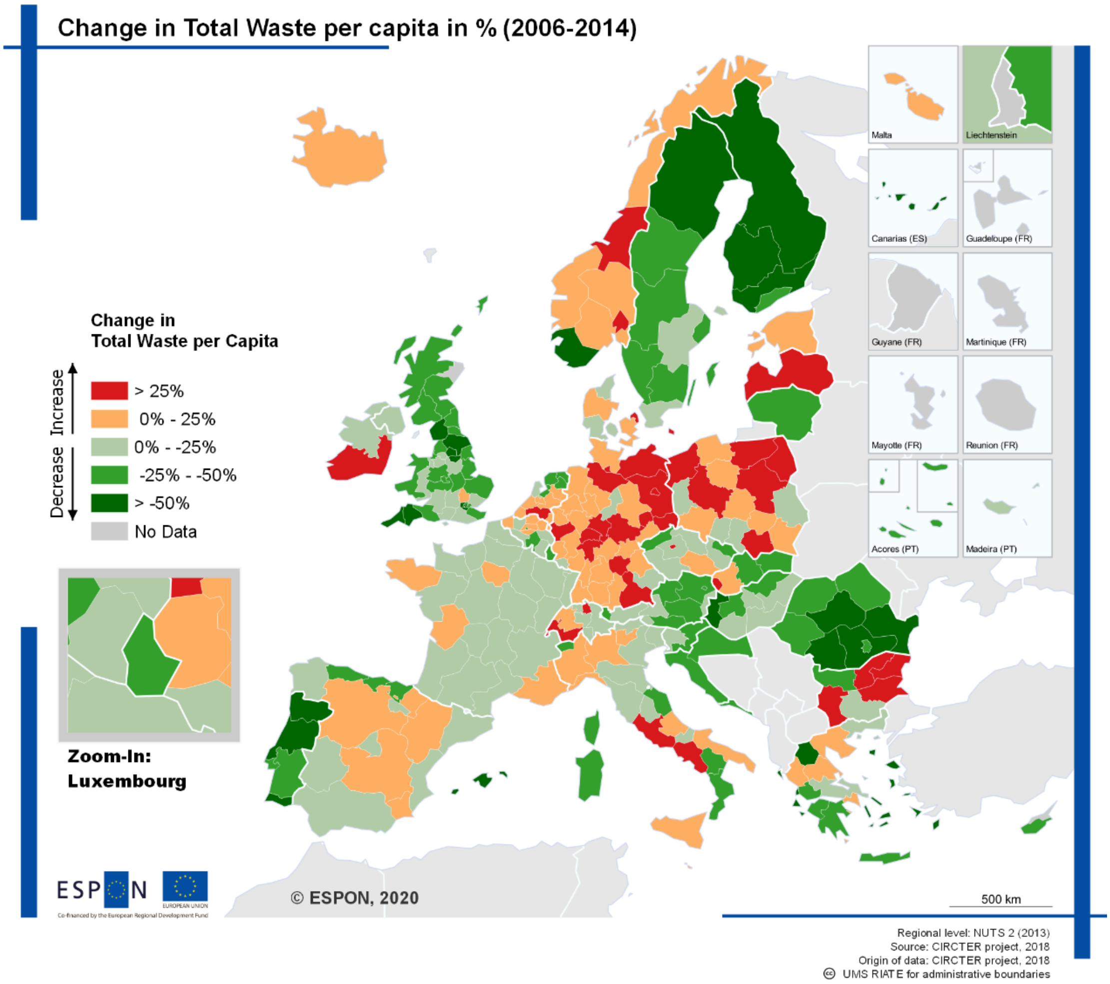
## Figure 2-5: Waste generation for a selected sample of regions (2006 vs 2014)




Source: own elaboration based on CIRCTER database

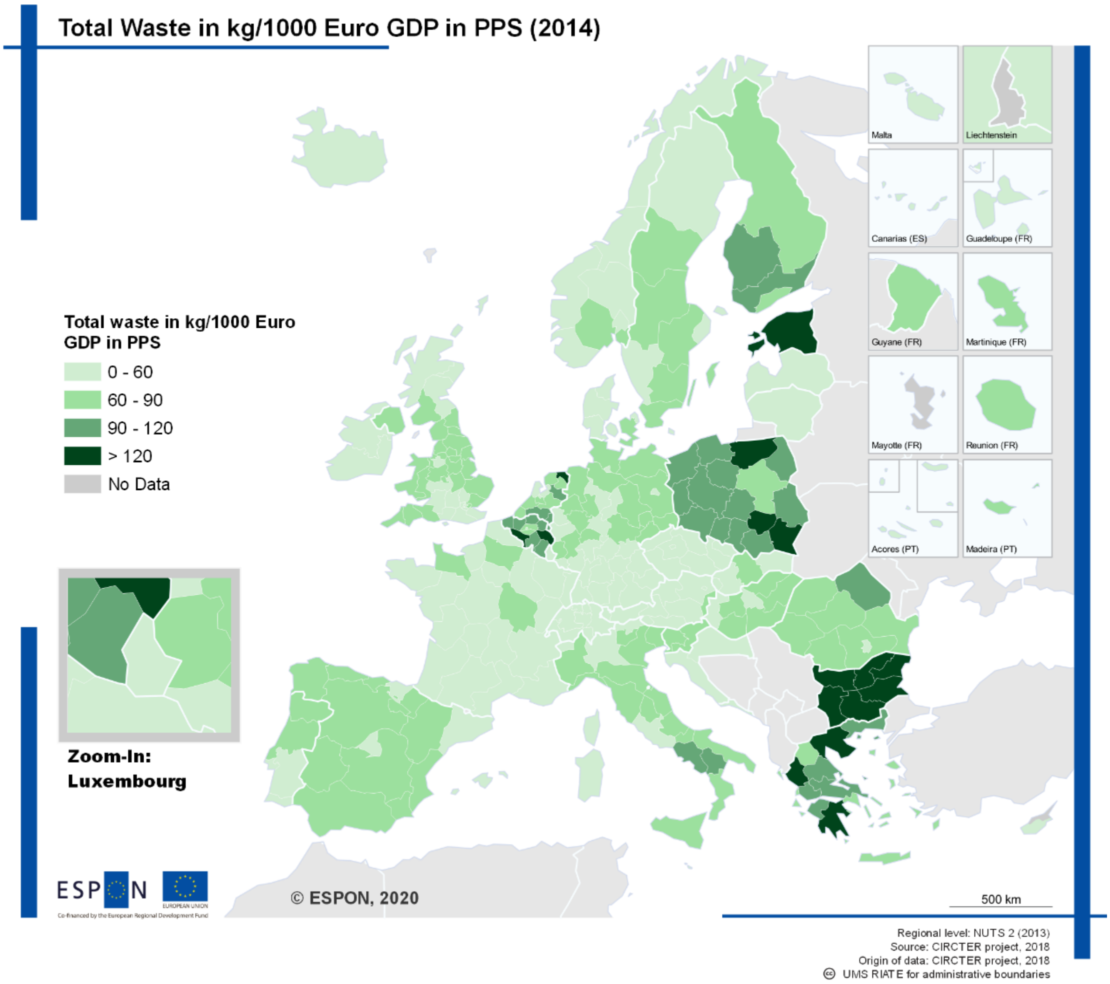
If we include the amount of net border workers in 2015, being this equal to 171.000 commuters (approximately 30% of the national population), the total waste generation per capita in Luxembourg would be equal to 1.25 t/cap, a figure well below the regional (NUTS 2) European average (1.7 t/cap). Luxembourg is not only one of the regions that better behaved in terms of waste generation in 2014, but, as shown in Map 2-5, it is also among those regions that succeeded the most in reducing waste generation in the analysed period, almost halving the generation rate per capita (-44%).

## Map 2-5 : Change of total waste (excluding major mineral waste) in kg per Capita in %




Similarly to what has been observed for DMC intensity, when considering waste generation in terms of Kg/Euro GDP in PPS, we find Luxembourg among the top five regions having the best performance at European level (21,58 kg/Euro PPS). This is not surprising considering Luxembourg economic structure, which is very specialised in the tertiary sector (see Section 2.3 Sectoral perspective). Indeed, financial and services activities not only generate higher added value compared to primary and secondary activities such as agriculture and/or manufacturing but are also less reliant on direct consumption of material and generation of waste. In this vein, it might be argued that Luxembourg exhibit a more dematerialised economy compared to similar regional peers as the generation of economic output is, to a great extent, delinked from the physical flows of material and waste (ESPON CIRCTER, 2019). However, it should also be pointed out that even if the offshoring of material intensive activities might translate in less environmental harm locally, the overall environmental impact remains unchanged due to the "shifting burden" issue among regions. In this sense, a production model with highly spatially segregated value chains and where each of the phases of the manufacturing process (as well as the production of the set of components) takes place in different corners of the world does not contribute in reducing the generation of waste and allowing a better use of the materials and products generated throughout the overall process. These aspects will be further discussed within the Section 4 Territorial implications.

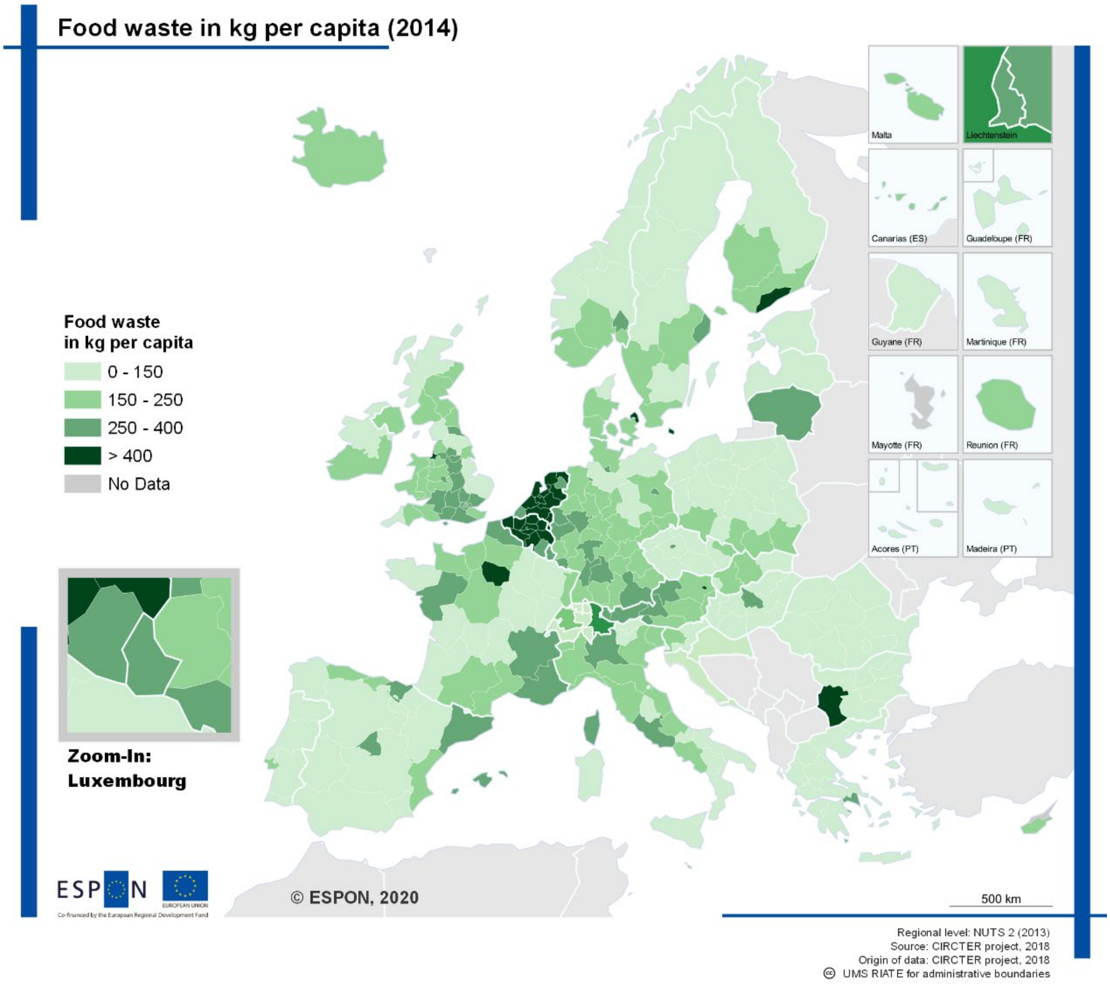
## Map 2-6: Waste intensity (total waste excluding major mineral waste)




Besides total waste generation, the CIRCTER project also produced a novel waste indicator related to food-waste, which is one of the priority areas identified by the EC (European Commission, 2015). Indeed, the European Union is committed to achieving the Sustainable Development Goal (SDG) 12.3. which, by 2030, aims to halve the volume of food waste globally per capita at the level of distribution and consumption and to reduce the loss of food products throughout production chains and supply, including post-harvest losses. Since the notion of food loss is not yet present in the EU regulatory framework and, hence, the respective monitoring cannot be effectively addressed through existing waste legislation, the CIRCTER project estimated food-waste indicator following the recommendation on food waste allocation by the Platform Food Losses and Food Waste, Subgroup on food waste measurement[4]. According to these guidelines' food-waste includes the animal and vegetal waste generated by economic activities plus a 25% of total household waste. Results for food waste are showed in Map 2-7.

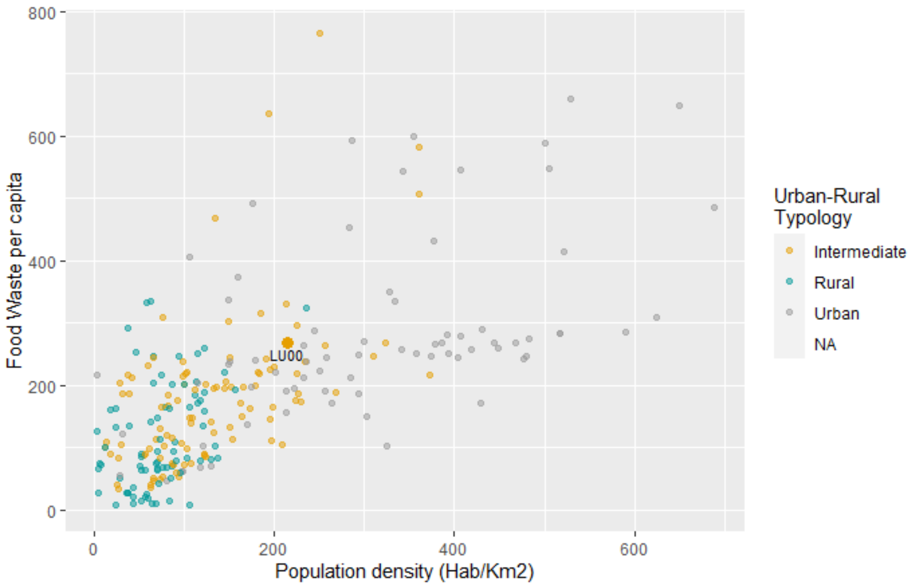
[4] https://ec.europa.eu/food/sites/food/files/safety/docs/fw_eu-platform_20170925_sub-fwm_pres-03.pdf

## Map 2-7: Food waste in kg per capita (2014)




When considering food waste, and more in general all biotic flows related with primary consumption, an important consideration has to be kept in mind. Differently from the production and consumption of physical materials, which benefit extremely from agglomerations and economies of scale, the consumption and waste generation of biomass is much more inelastic to agglomeration factors. In other words, the diet, understood in a functional sense, does not change according to whether people live in a more or less densely populated place, nor does it change according to the economic structure of a territory. If anything, rural and sparsely populated regions may be better off as most biotic waste is directly composted or recycled on-site (i.e. food for animals) and thus less food waste per household will be collected compared to urban regions. This explains why the highest figures for food waste per capita are generally recorded in urban regions (Figure 2-6).

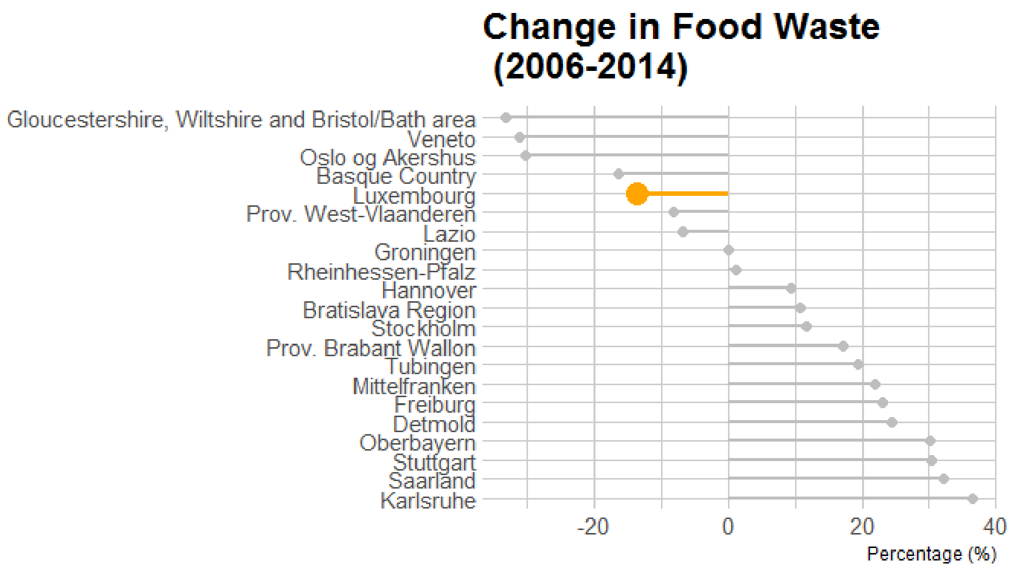
## Figure 2-6: Food-waste per capita vs. Population density (2014)




Source: own elaboration based on CIRCTER data.

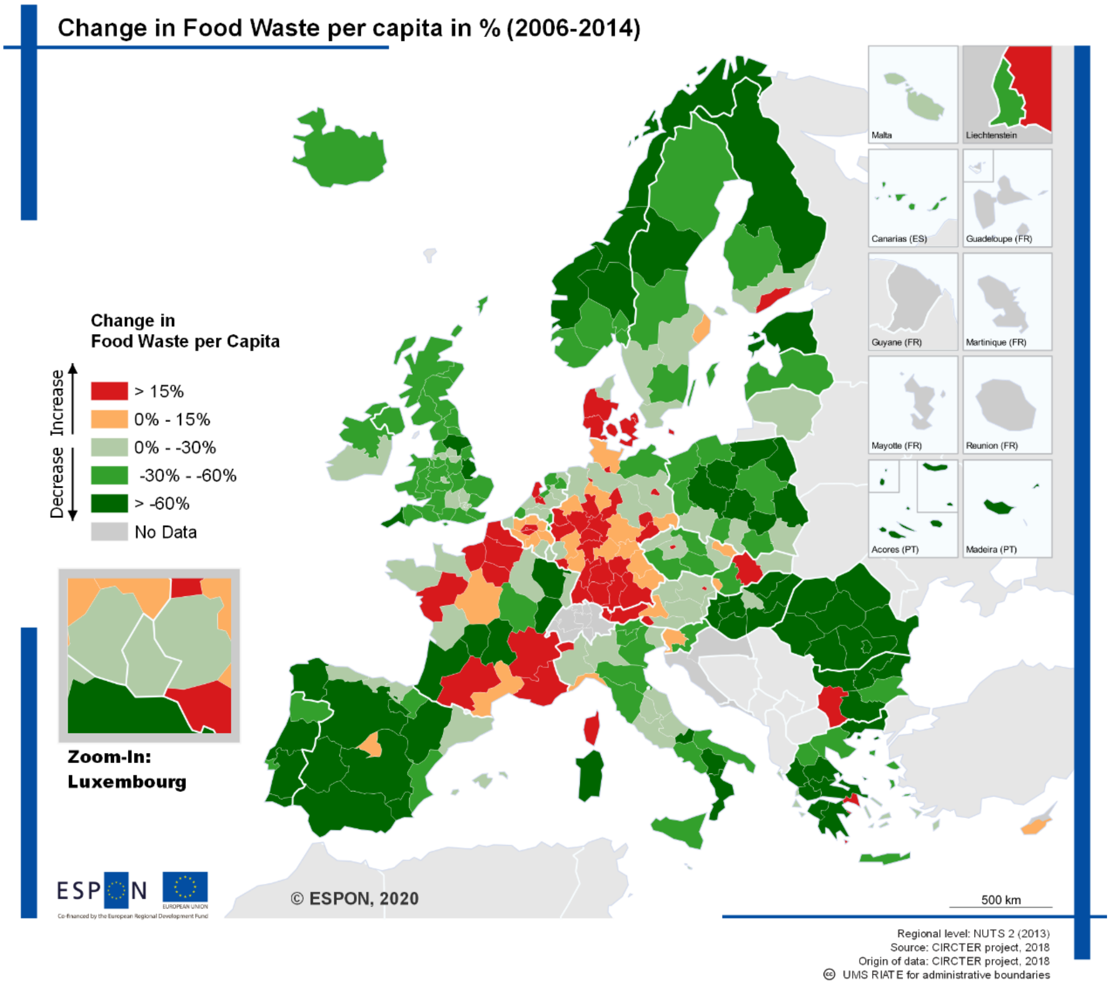
Map 2-8 shows the change of food waste per capita between 2006 and 2014. Once again, densely populated regions appear to be struggling most to meet food waste reduction targets (e.g. Madrid, Île de France, Berlin etc.). Conversely, Luxembourg's performance appears to be significantly better as it managed to reduce food waste by 14% over the period under review. This can be appreciated even more when we consider our sample of regions with similar socio-economic factors. Luxembourg is among the few regions that have managed to reduce the production of food waste, confirming itself on the right path towards SDG 12.3.

## Figure 2-7: Change in Food Waste for a selected sample of regions (2006-2014)




Source: own elaboration based on CIRCTER data

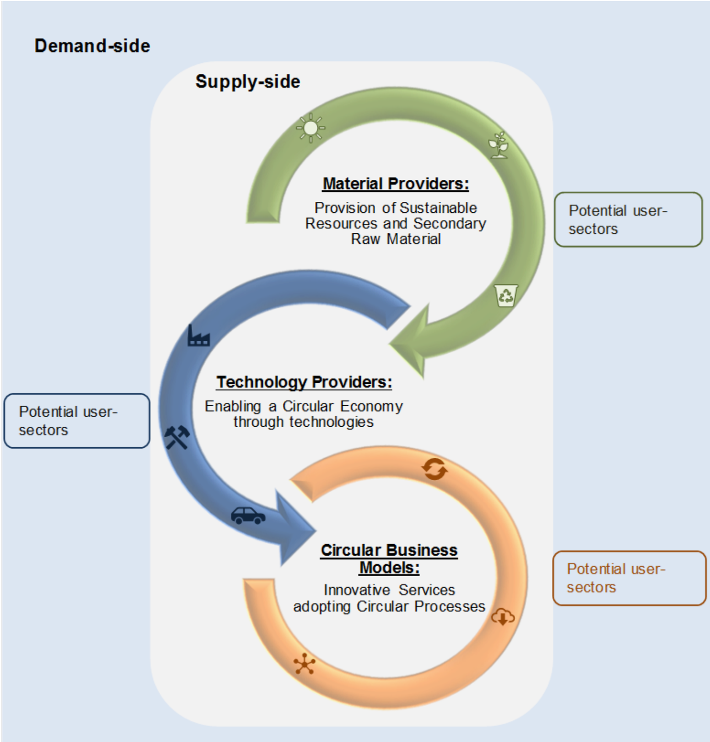
### Map 2-8: Change of Food Waste per capita, 2006-2014




## 2.3 Sectoral perspective of Circular Business Models and Potential User

Next to the indicators concerning material and waste patterns commonly used to measure the progress towards closed-loop systems, CIRCTER project developed a new set of indicators related to the economic activities promoting circular businesses. The sectoral definition established in the CIRCTER project distinguishes between the supply-side and demand-side of the economy (Figure 2-8). The supply side is defined as the provision of materials, technologies and services for a CE and it is represented by the Material Providers, Technology Providers and Circular Business Models. On the other hand, the demand-side is defined as selected industries that adopt or rather demand new circular business processes, products and technologies that drive their uptake. These are referred to as Potential Users (ESPON CIRCTER, 2019).

### Figure 2-8: A conceptual visualisation of the four pillars of a Circular Economy and their respective sectors




Source: CIRCTER project 2019.

Since figures for Material Providers and Technology Providers are not available for Luxembourg region, we will focus only on Circular Business Models (CBM) and Potential Users (PU). CBMs facilitate the up-take of circular processes through innovative services and new forms of consumption by connecting businesses to businesses (B2B), businesses to consumers (B2C) and consumers to consumers (C2C). Therefore, CBM indicators measure employment and turnover generated by four overarching circular business models: (i) Long life design, (ii) Extending product and resource value, (iii) Encourage sufficiency and shifting utilisation patterns and (iv) Access, sharing and performance model (Figure 2-9).

### Figure 2-9: The four overarching Circular Business Models

| CE Business Model | Description | Contribution to a CE | Examples |
|---|---|---|---|
| Long Life Design | Models focused on delivering long-life-products, supporting design for durability and repair. | ▪ Supporting long-life-products through design for repair, refurbishment and remanufacturing – focus on product design.<br>▪ Essential part of the company's normal design ethos, often linked to the concept of eco-design and geared towards disassembly. | Modular Design, Cradle-to-Cradle Design, Eco-Design |
| Extending Product and Resource Value | Exploiting residual value of products. | ▪ Exploiting the residual value of products.<br>▪ Collecting and reselling refurbished products and / or components.<br>▪ Often reffered to as ‚closing the loop'. | Remanufacturing, refurbishment, upcycle, take-back systems |
| Encourage sufficiency and shifting utilisation patterns | Seeking to reduce end-user consumption and delivering utilities virtually rather than materially | ▪ Supporting sufficiency and shifting utilisation patterns – focus on consumers.<br>▪ Digitising business products and services.<br>▪ Shift in demand patterns through technology as consumers choose virtual products or services | Pay-per-Service, Re-commerce, reuse cafés |
| Access, Sharing and Performance Model | Providing the capacity of services to satisfy user needs without needing to own physical products | ▪ Manufacturer or service provider retains ownership of the product.<br>▪ Sharing models seeking to reduce under-utilisation of products, facilitated by digital technology and social platforms. | Car-sharing, Carpooling, tool sharing, office shares |

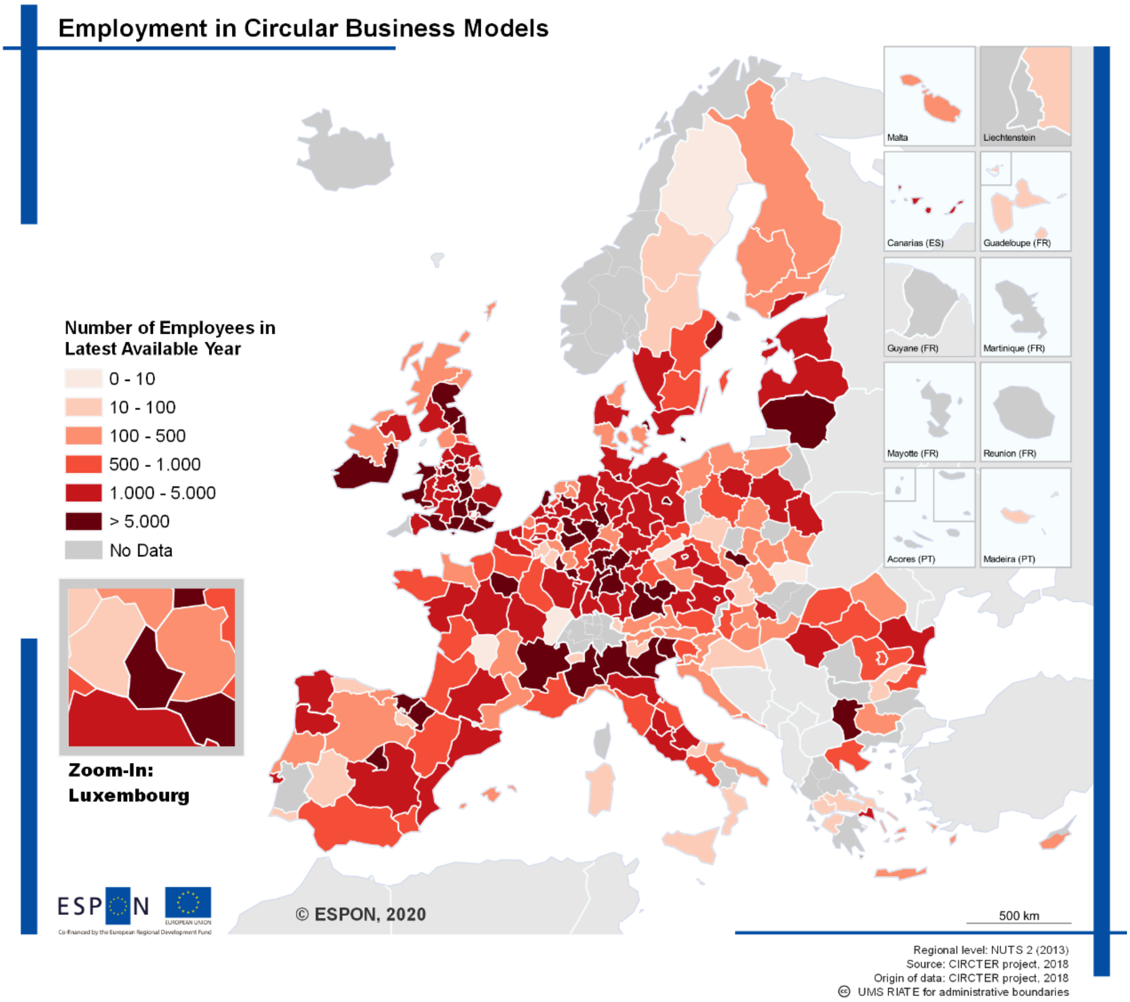
Source: CIRCTER project 2019

Finally, the Potential Users (PU), which represent the demand side of the economy, are defined as those industries that adopt or rather demand new circular business processes, products and technologies that drive their uptake. Since the primary focus of PU is the endorsement of Circular Economy processes at the sectoral level, their specific needs and choices tend to foretell those of the general market. In this sense, PU indicators measure the revenues generated by selected key-sectors most likely related with circular economy activities.

### 2.3.1 Luxembourg: Circular Business Models

Map 2-9 shows the number of persons employed in companies making use of, or are very related to, CBMs. As it might be expected, most of the CBM employment concentrates above all in highly populated regions. Very urbanised regions such as Greater London, Madrid, Ile de France or Lombardy are favoured by their agglomeration economies, which ultimately favour the deployment of circular business models. Urban proximity can promote strategies such as take-back programmes or reverse logistics for a reliable stream of secondary materials. Similarly, knowledge centres, universities or R&D are often located next to urbanised areas. These are further enabler factors boosting innovation capacities and can be a decisive factor for the development of disruptive products and/or resource efficient processes.

**Map 2-9: Number of persons employed in companies associated with Circular Business Models**



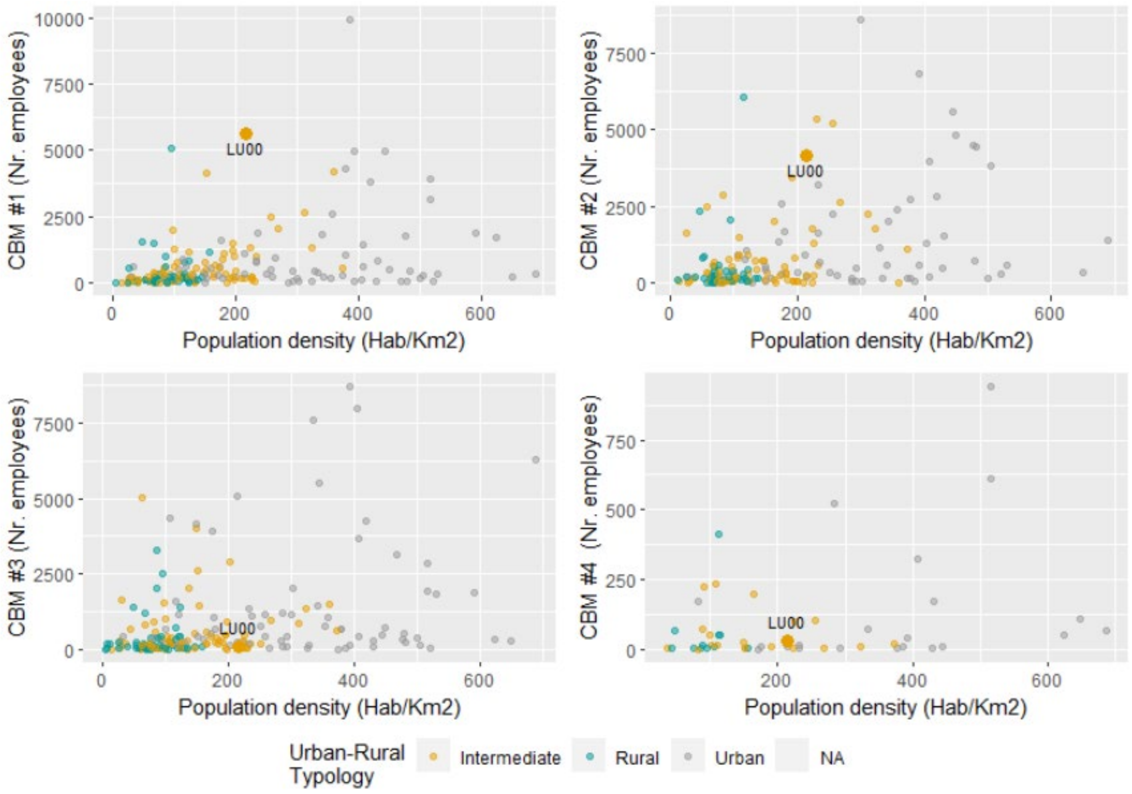

Despite its reduced magnitude in terms of total population, Luxembourg presents one of the highest figures in CBMs employment in Europe, that is 9.895 employees. This figure, which is perfectly in line with the rank estimated in EPEA's study "Luxembourg as a knowledge capital and testing ground for the circular economy"

[5], suggests that Luxembourg not only is among the most active European regions dealing with Circular Economy challenges, but also that circular economy concepts and strategies have already been, to a great extent, operationalised and transferred to the regional market.

However, if we focus on the specific CBMs we see that the number of employees is distributed very unevenly across the four overarching CBMs. According to Figure 2-10, which shows the number of employees by type of CBMs, Luxembourg's CBMs are somehow skewed towards the production side of the economy. In this sense, the business models focused on the delivery of long-lasting products (CBM #1) or on the exploitation of the secondary material or the residual values of the products (CBM #2) are those most installed in the productive fabric of the region.

Contrarywise, consumer-oriented CBMs seem to be more immature, as Luxembourg employment is in the bottom end of the graphs. Estimated figures for business models geared towards changing usage patterns (CBM # 3) and business models targeting shared usage configurations (CBM # 4) count only 120 employees in all.

## Figure 2-10: Number of employees by type of CBMs.



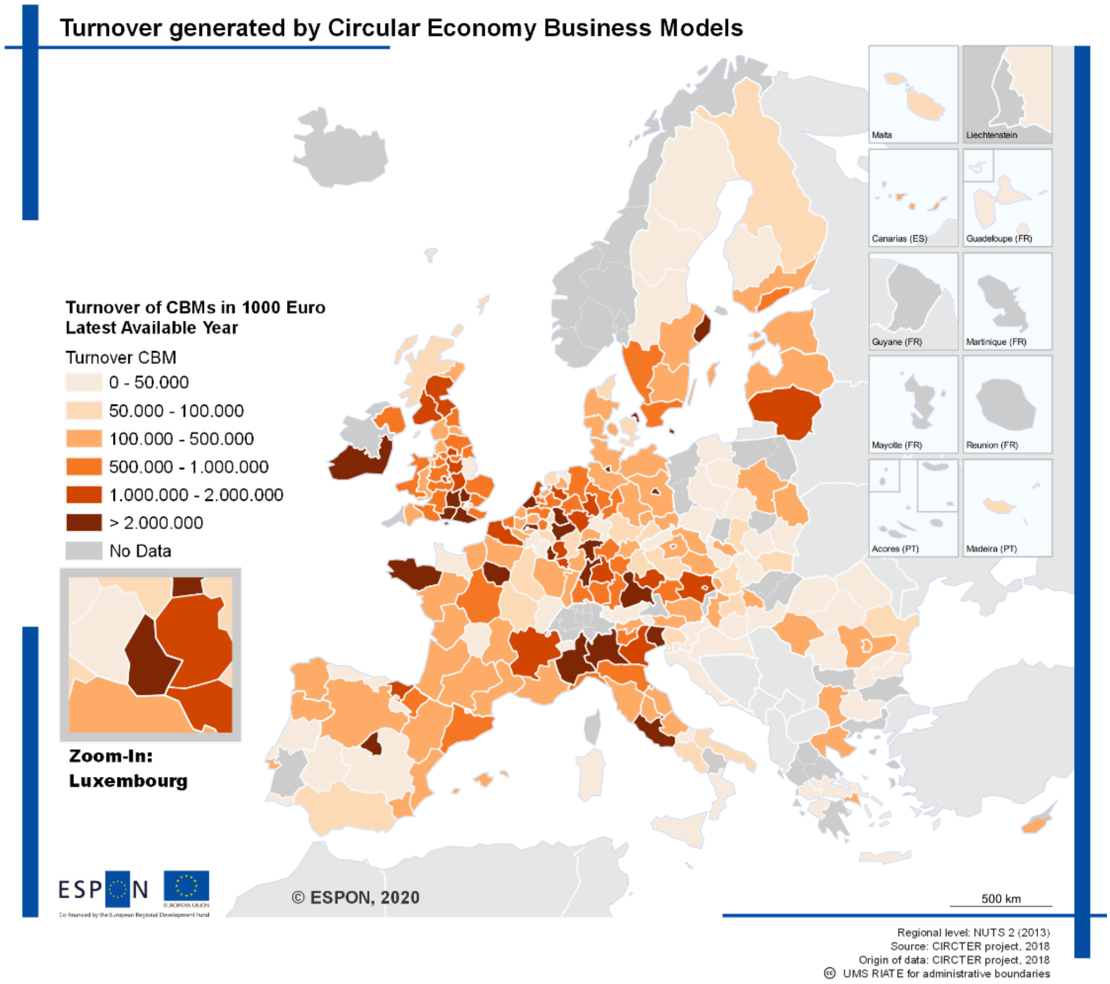

Source: own elaboration based on CIRCTER data.

Similar conclusions can be drawn considering the turnover generated by CBMs (Map 2-10). According to CIRCTER results, Luxembourg produced a turnover bigger than €3 billion annually. This was mostly related with CBM #1 (€1.5 billion) and CBM #2 (€1.1 billion). However, it should be point out that the limited reach of CBM #3 and CBM #4 might also be due to the inherent nature of their business models rather than under-developed know-hows. In fact, while circular activities oriented to production or process enhancement can be easily internalised within the strategy of a company, and hence they reach a larger multitude of actors in the market, CBMs oriented to shared fashion of consumption are generally implemented by specific –often new– actors that, in general, bring the platform architecture in the market. Therefore, it is not surprising that

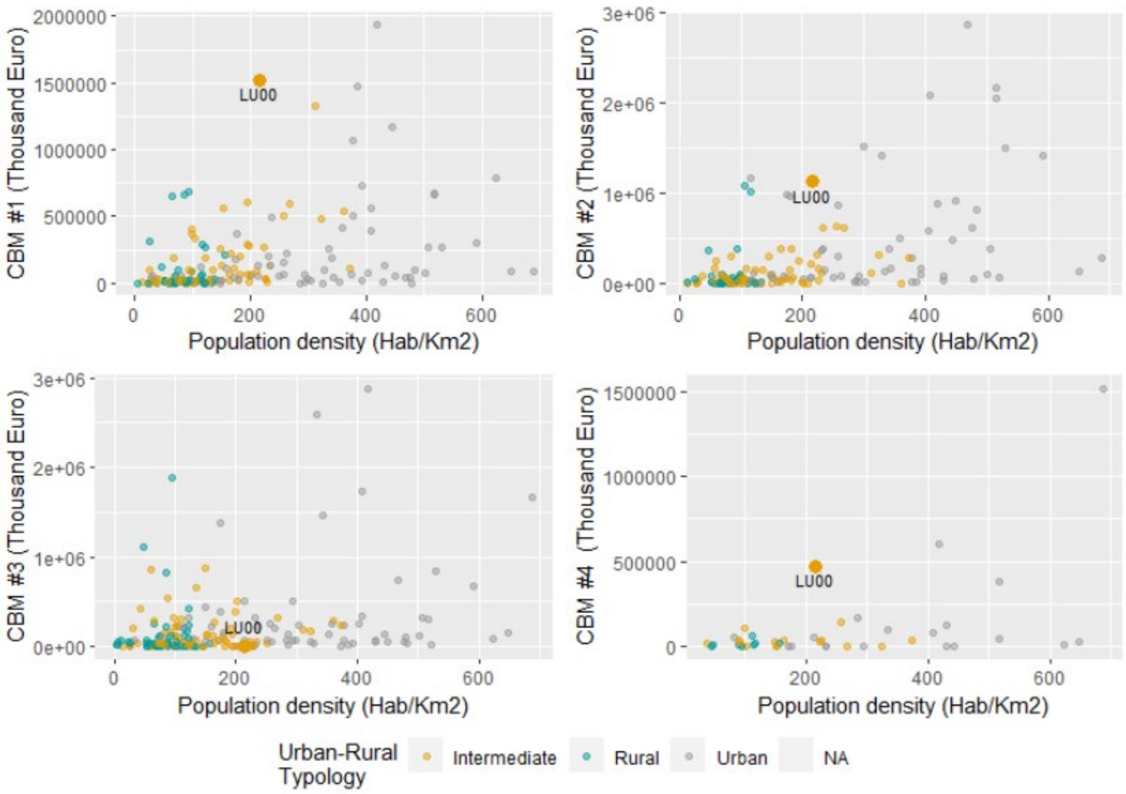
[5] According to the study circular economy supports between 7.000 and 15.000 jobs (EPEA, 2014, p. 9).

despite Luxembourg has a very low employment in sharing and performance models, it exhibits a rather high turnover in the same category compared with other European regions (bottom-right scatterplot in Figure 2-11).

## Map 2-10: Turnover in companies associated with Circular Economy Business Models



## Figure 2-11: Turnover generated by type of CBMs



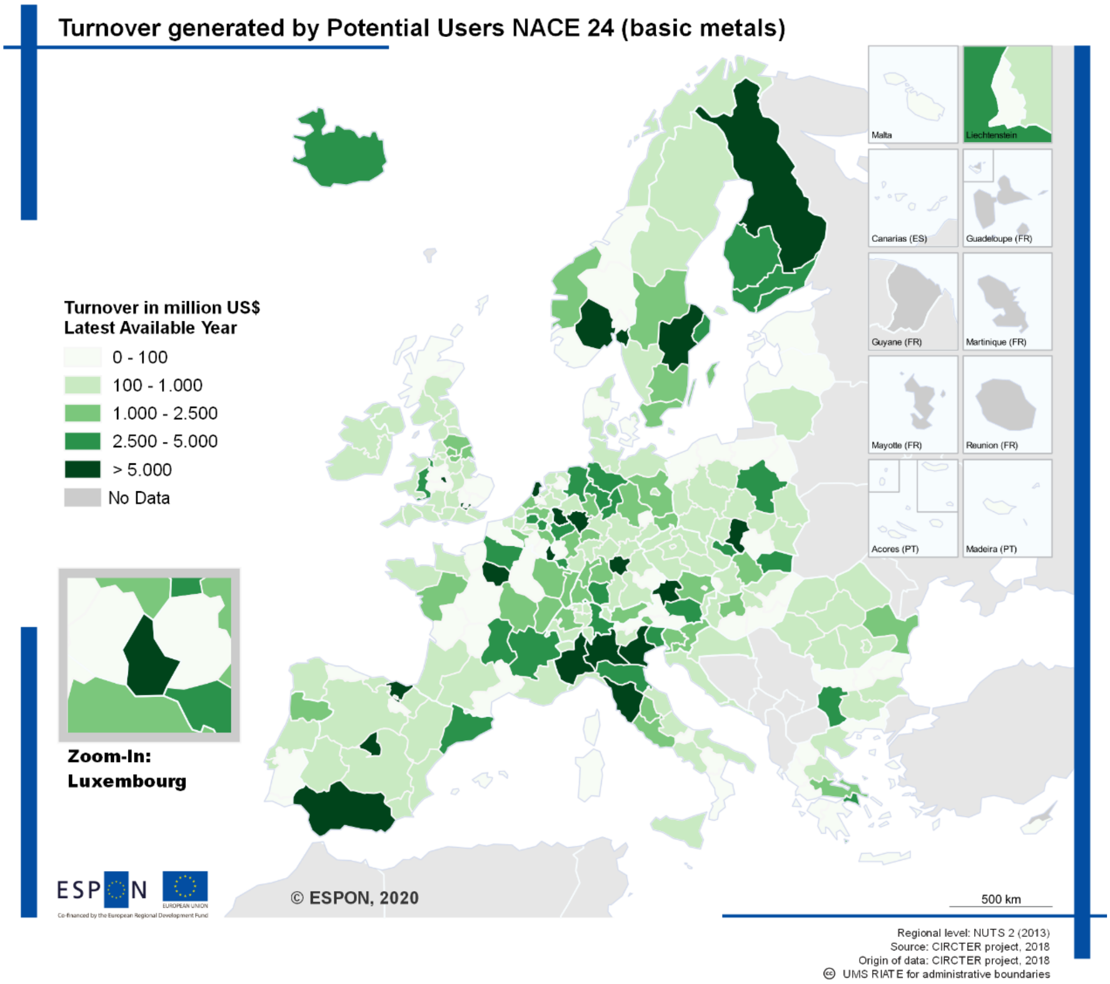

Source: own elaboration based on CIRCTER data

### 2.3.2 Luxembourg: Potential Users

The CIRCTER project produced Potential Users figures for the following key-sectors: Manufacture of basic metals (NACE 24) and Manufacture of fabricated metal products, except machinery and equipment (NACE 25), automotive industries (NACE 29 and 30), chemical and pharmaceutical industry (NACE 20 and 21), electronics industry (NACE 26 and 27) and the construction sector (NACE 41 to 43) (CIRCTER, Annex 4).

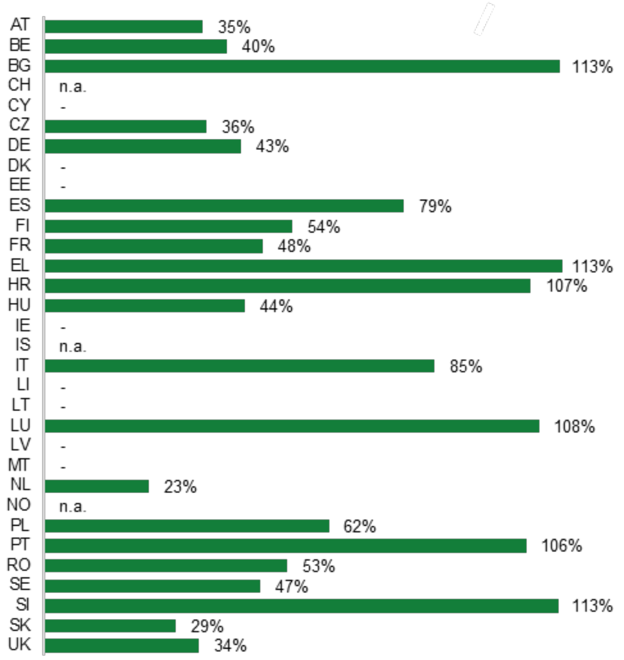
We present here only the map of "Manufacture of basic metals" (NACE 24), as the processing of metallic material represents one of the most significant activities in Luxembourg among the sectors selected. According with the estimates, Luxembourg is the European region with the biggest turnover generated by the manufacturing of basic metals, i.e. US $86 million (Map 2-11).

## Map 2-11: Regional Distribution of Revenue of Potential Users by NACE 24 (basic metals) category




In addition, if we focus on the share of iron scrap used by the manufacture of basic metals (Figure 2-12), we can see that Luxembourg presents a production system highly demanding on secondary raw materials as it reuses the 100% of iron scrap. Considering this sector as a circular activity, this results in rather high performance on this type of indicator. The overall circularity of Luxembourg will be further analysed in the following chapter.

## Figure 2-12: Share of iron scrap consumption NACE 24



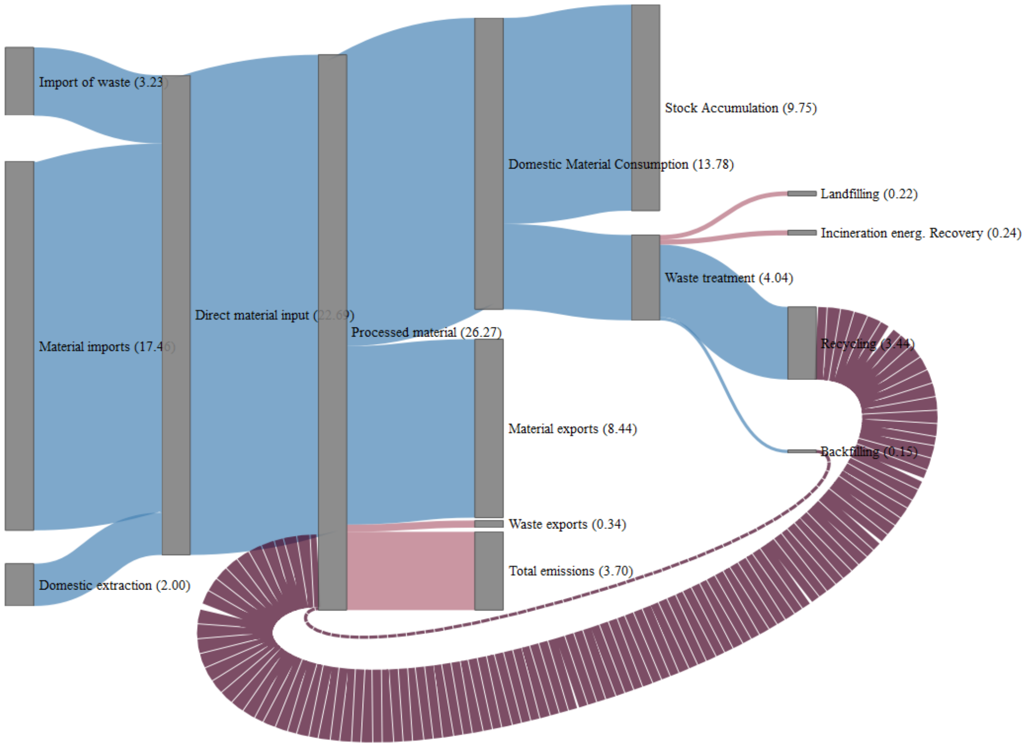

Source: (ESPON CIRCTER, 2019)

# 3 Luxembourg's metabolism

This chapter takes a closer view on the material and waste flows previously described in order to provide additional insights on Luxembourg's metabolism, and hence, a better understanding of the more incipient challenges towards closed-loop systems.

Figure 3-1 shows a Sankey diagram of the aggregated flows of material and waste in Luxembourg in 2016. The Sankey diagram has been built following EUROSTAT guidelines, which, in order to avoid double counting or counting waste not included in domestic extraction, suggest excluding specific categories of waste[6]. Specifically, "soils waste", i.e. soils and stones that originate mainly from construction activities, the excavation of contaminated sites and soil remediation, have been excluded since they are not considered within material flows accounting. However, since this type of residue represents a critical challenge in terms of waste treatments towards circularity, we included it when considering waste treatment streams (Section 3.2, Figure 3-9). Similarly, total emissions in Sankey diagrams are modelled in order to be combined consistently with material flows accounts. Therefore, these are calculated net of balancing items[7] and do not equal the Luxembourg's total real emissions accounted for in emission databases – according to the EEA's statistical database, Luxembourg's greenhouse gasses in 2016 was 9.5 million tonnes.

## Figure 3-1: Luxembourg Sankey diagram: aggregated material and waste flows; Million tonnes, 2016




Source: own elaboration based on EUROSTAT "env_wastrt", "env_ac_mfa" and "env_ac_sd". Note that according to EUROSTAT guidelines "soils waste" are excluded in order to avoid double counting or counting waste not included in domestic extraction.

[6] These are Sludges and liquid wastes from waste treatment (W033), Animal faeces, urine and manure (W093), Soils (W126), Dredging spoils (W127), Mineral wastes from waste treatment and stabilised wastes (W128_13)

[7] Balancing items (BI) enable the balancing of material input and output related to a national economy. Two groupings of balancing items are distinguishable: BI to be added to material input, such as oxygen for combustion processes and respiration, and nitrogen; BI to be added to material output, such as water vapour from combustion and gases from respiration. 'Total BI' designates the difference between 'BI: input side' and 'BI: output side', i.e. 'BI (input-output)'.

According to Figure 3-1, some important considerations can be made. First of all, Luxembourg seems to present a very efficient waste management system in which most of the treated waste is fed back, as secondary material, to the economy through recycling and/or backfilling[8] operations (purple loops from recycling and backfilling to processed material). The recycling stream, as it will be shown in the following chapter, is mainly characterised by metallic residuals. The amount of waste destined for landfills and incineration, which represent the less desirable treatment options according to the waste hierarchy, is much smaller, even if we should remind that soils waste is not considered at this point. The second important consideration concerns the reliance of Luxembourg economy on imported materials. Indeed, due to the exhaustion of domestic resources, imports of materials and waste destined for recovery are the main source of inputs for Luxembourg.

The “Circular material use rate (CMU)” (Eurostat, 2018) of Luxembourg in 2016 is equal to 4%, which is much less than the European average (11%). However, the lower performance of Luxembourg is mainly due to the biasness of the indicator rather than the circularity performance of Luxembourg. In fact, CMU indicator is constructed in order to reward countries’ effort to collect internal waste for recovery, therefore it subtracts imported waste and adds up exported waste. This perspective credits the country’s effort to gather internally waste bound for recovery, which indirectly contributes to the worldwide supply of secondary materials and hence reduction of primary material extractions. However, it could be argued that the CMU’s definition neglects the overall country’s effort to reuse secondary material into its own economy. In the case of Luxembourg this omission is crucial as Luxembourg relies on huge inflows of metal residues to supply its manufacturing industry. If we estimate the CMU rate as the share of secondary material used by Luxembourgish economy, the CMU indicator would reach 31%. In other words, 31% of the processed material in Luxembourg comes from secondary materials.

Next section will focus on the historic trends and composition of material flows.

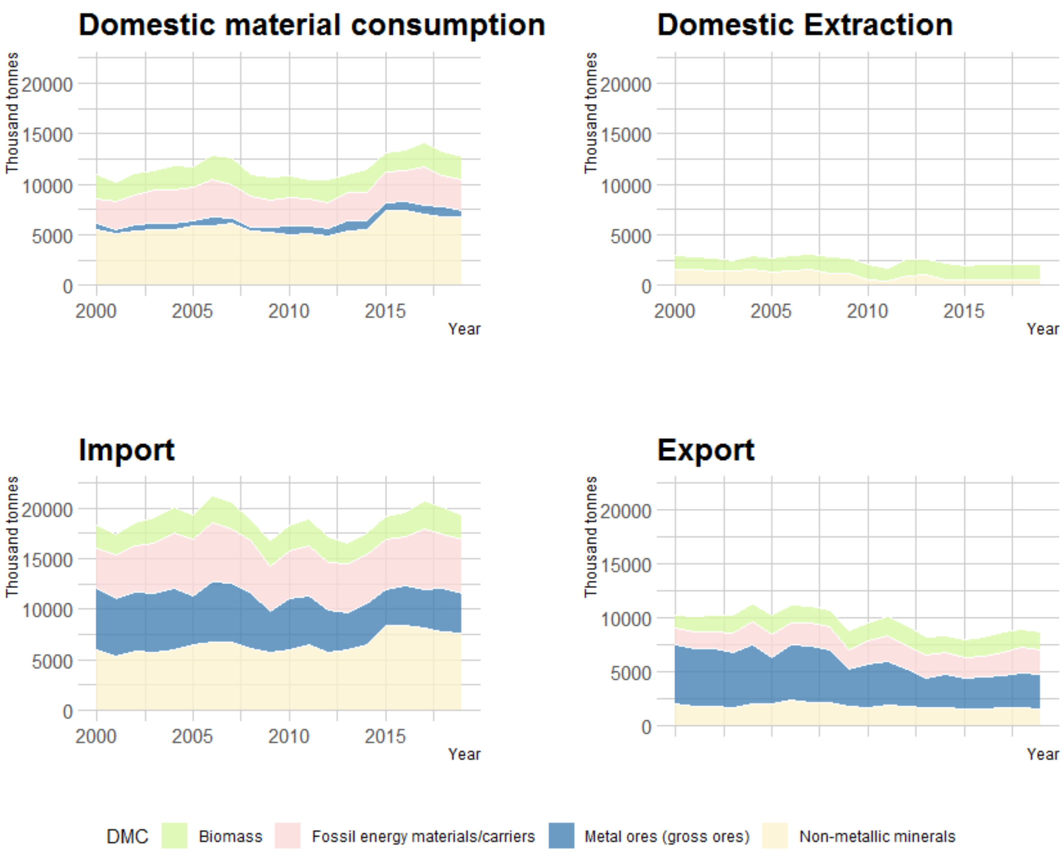
## 3.1 Luxembourg material flows breakdown

Figure 3-2 shows the evolution of specific material flows during the 2000-2018 period. The time series for these data were retrieved form EUROSTAT (env_ac_mfa) as CIRCTER project only provided figures for 2006 and 2014.

Natural resources extracted in Luxembourg only refer to biomass and non-metallic mineral material. Fodder crops and grazed biomass represent together the highest share of domestic biomass (58%), followed by wood, which account for the 33% of the total biomass. On the other hand, non-metallic minerals are composed exclusively by construction material, namely sand and gravel. Differently, from biomass flow, which remained stable over the period considered, extraction of construction material more than halved between 2000 and 2018, possibly due to the exhaustion of this limited resource.

[8] Backfilling means a recovery operation where waste is used in excavated areas (such as underground mines, gravel pits) for the purpose of slope reclamation or safety or for engineering purposes in landscaping and where the waste is substituting other non-waste materials which would have had to be used for the purpose.

**Figure 3-2: Evolution of DMC, DE, Import and Export by material flow typology (2000-2018)**

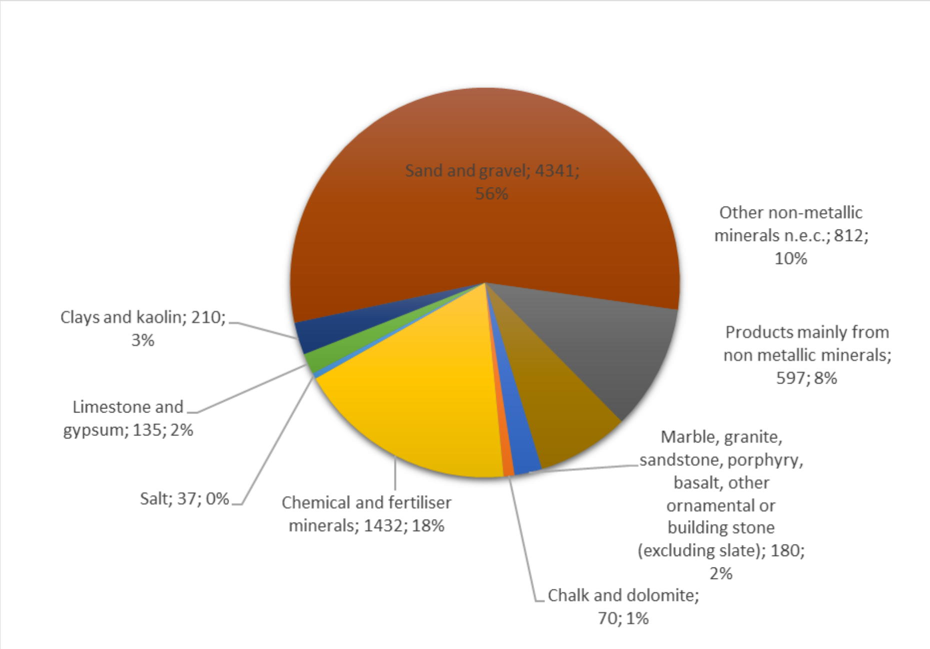



Source: own elaboration based on EUROSTAT “env_ac_mfa” database

Luxembourg’s DMC is dominated by construction materials (non-metallic minerals), which makes up more than half of the total. Biomass and fossil energy each make up approximately a quarter of DMC. Metal ores constitute the smallest of the four main material categories. These figures are in line with European average of material consumption shares. Focusing on the temporal evolution, it can be seen that the unique flow that increased over the period considered, is constituted by the use of construction materials. The steady economic expansion of Luxembourg, and hence the growth of domestic population[9], have in fact translated into an ever growing demand for building materials – especially sand and gravel – increasingly covered by imports (Figure 3-3). This trend is really in contrast with the European experience which, due to the financial and economic crisis, recorded a sharp decline in the use of construction materials since 2008.

[9] Luxembourg is by far the country with the highest population growth rate in Europe (1.98% in 2017).

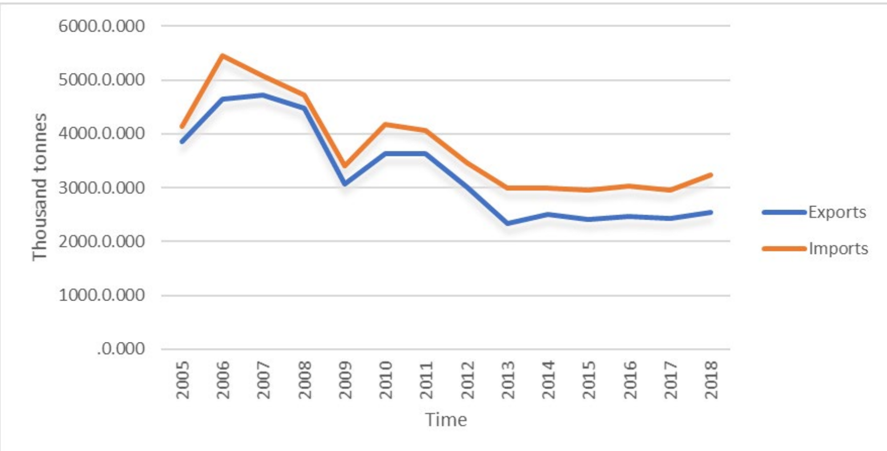
## Figure 3-3: Import shares of non-metallic materials in thousand tonnes (construction and building materials), (2018)




Source: own elaboration based on EUROSTAT "env_ac_mfa" database

Metal ores is another material pattern that draws attention. Indeed, iron and steel historically represented the backbone of the Luxembourg economy, where ArcelorMittal remains the largest corporate employer in the country. Despite the iron industry's participation to the whole economy has declined in relative terms, steel and iron are still the most exported materials, accounting one third of total exports. However, as explained above, due to the reduced availability of direct natural resources, the steel industry of Luxembourg is entirely relying on imports of both raw metallic materials and scrap metal. As shown in Figure 3-4, imports and export of metallic materials are very coupled each other. In terms of resilience of the Luxembourgish economy this may represent a factor of risk which could eventually be mitigated with the implementation of circular strategies aimed at returning embedded metal in abandoned infrastructures/buildings and other potential sources from the urban mine back into economic cycles.

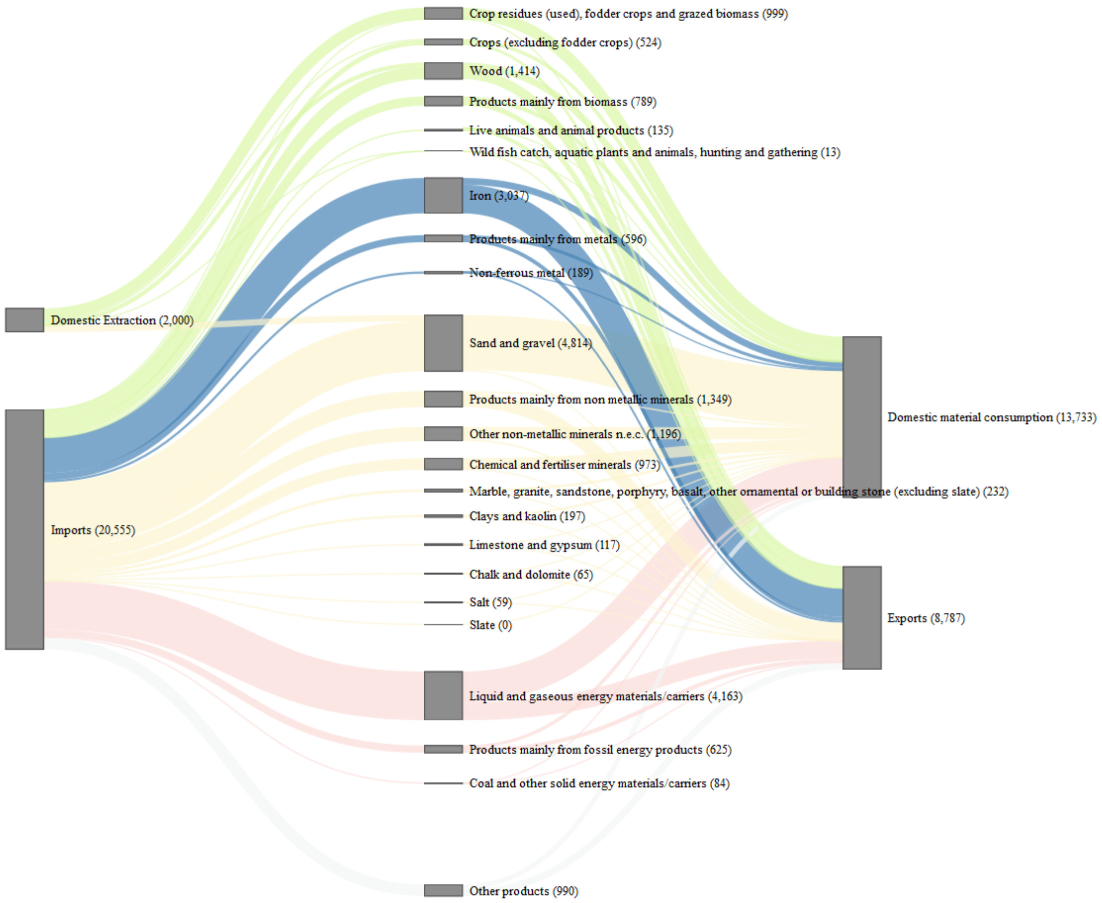
## Figure 3-4: Import and Export of metallic materials




Source: own elaboration based on EUROSTAT "env_ac_mfa" database

Figure 3-5 provides, in granular detail, the flows of materials entering and leaving the Luxembourgish economy. The colours reflect the macro material flows categories, namely: biomass (green), metallic minerals (blue), non-metallic minerals (orange) and energy materials (red). The biggest flows are constituted by sand and gravel flow, mainly lead by construction sector, and liquid and gaseous energy material/carriers flow, as result of domestic energy demand and transport sector. While the entire amount of sand and gravel is destined for the internal market for construction activities, a significant share of energy and carrier materials is exported. On the contrary, the flow of iron, entirely imported from abroad, is almost exclusively destined for the foreign market. The reduced flows of metallic ores consumed domestically refer to material consumed during production processes or finished products ending up in the built stock of Luxembourg infrastructure.

**Figure 3-5: Sankey diagram of economic-wide material flows (tonnes, 2016)**



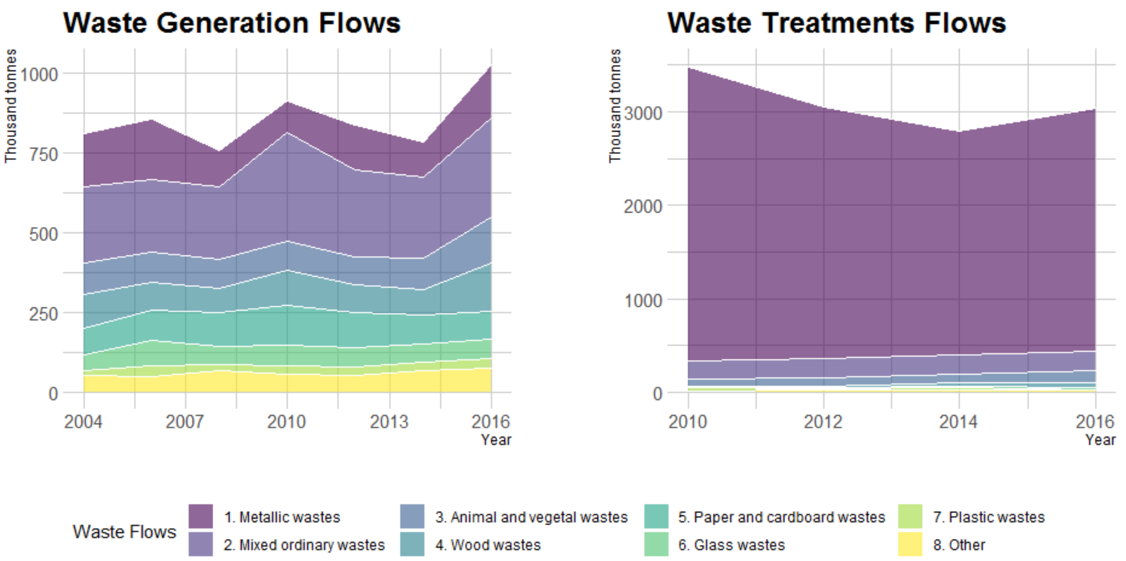

Source: own elaboration based on EUROSTAT “env_ac_mfa” database

## 3.2 Luxembourg: waste flows breakdown

Figure 3-6 shows the size of waste flows by waste categories[10]. First of all, it can be observed that the treated waste (excluding major mineral waste) is roughly threefold the waste generated in Luxembourg. This is explained by the metallic waste that Luxembourg imports annually to recycle and re-use as secondary material in domestic manufacturing processes. Indeed, Luxembourg is one of the bigger traders of metallic waste in Europe and its imports, mostly concerning iron and steel waste, amounts to more than 2 Gigatons yearly.

[10] We excluded the major mineral waste category as due to its magnitude it would “dilute” remaing waste flows;

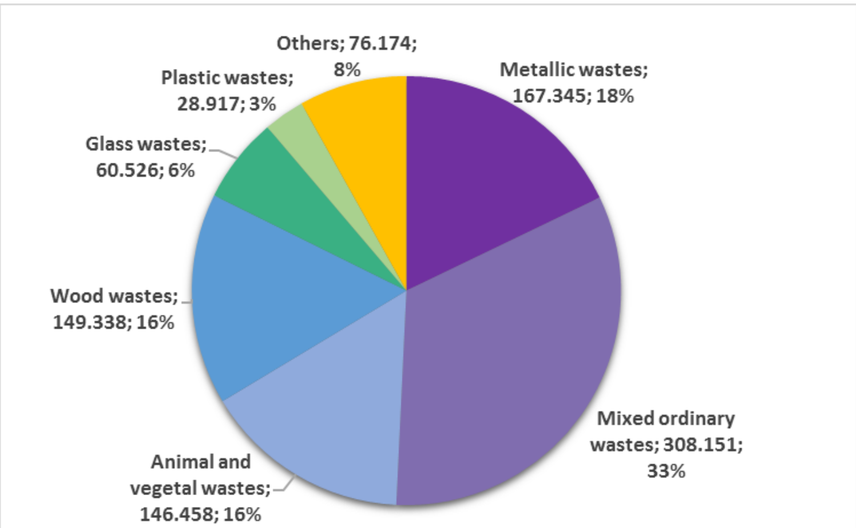
## Figure 3-6: Waste generation and treatment flows excluding major mineral waste (figures in thousand tonnes)




Own elaboration based on Eurostat “env_wasgen” and “env_wastrt”

Concerning waste generation, Luxembourg produces a rather balanced mix of waste typologies, being the mixed ordinary waste the biggest category (Figure 3-7). This accounts the 33% of generated waste and it is followed by metallic, wood and organic waste. Mixed ordinary waste includes mostly household and similar waste along with mixed and undifferentiated materials and sorting residues (European Commission, 2013). Due to the type of waste included in this category, mixed ordinary waste exhibits per capita figures very close to the municipal waste figures presented in the Plan National de Gestion des Dechets et des Ressources (PNGD), i.e. 535 kg/cap in 2016. Besides being the biggest type of waste, mixed ordinary waste has also undergone a significant increase during the period 2004-2016 (+28%). Even if this historical trend reflects the population growth of Luxembourg in the same period (+27%), it also suggests that there is still significant room for improvement in (i) waste management activities (collection & sorting) and (ii) eco-design manufacturing. Mixed ordinary waste is, in fact, mostly directed to incineration and/or landfilling, hence mis-using potential secondary resources.

## Figure 3-7: Waste generated by waste category, excluding major mineral wastes (2016)

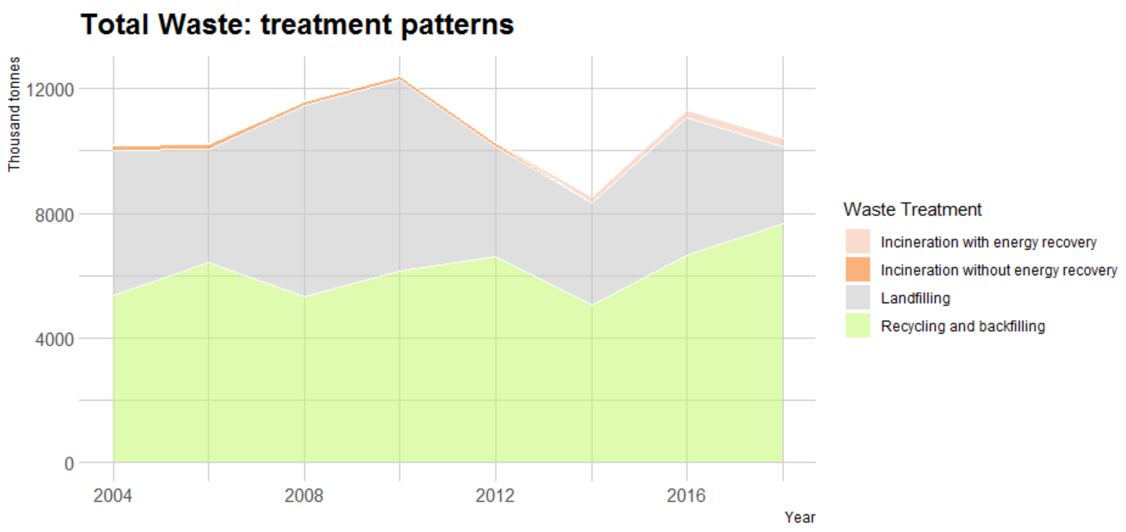



Own elaboration based on Eurostat “env_wasgen”.

In addition to the total amount of waste generated, an equally important criterion to assess whether a region is progressing towards a circular system is how the different typologies of waste are handled. Within the CIRCTER project this analysis mainly relied on a pilot municipal waste database collected until 2013, since waste treatment statistics are regularly provided only at national level. In the case of Luxembourg, this limitation does not exist, since the regional and country levels are the same. This allowed us to rely on more robust data for the analysis of waste treatment modes. On one hand we referred directly to the waste treatment ("env_wastrt") Eurostat database. This provides figures on treatment modes for the overall amount of waste in Luxembourg (i.e. municipal and industrial) by waste typology and waste treatment option. On the other hand, we considered the STATEC database to have a deeper understanding on the municipal waste patterns and related treatment options characterising Luxembourg.

Figure 3-8 shows how the total amount of waste has been treated during the period 2004-2018 in Luxembourg. This time, non-metallic material, i.e. construction waste as well as excavated soils (i.e. rubble), have been included in the chart. Overall, more than 7.5 million tonnes of waste have been reused in the economy, of these 4.2 million through recycling processes (mainly concerning metallic materials) and 3.4 million through backfilling (mainly related to construction and inert wastes). On the positive side, Luxembourg has been able to progressively increase the reusing rate of waste material. In addition, it also phased out incineration without energy recovery (last figures refer to 2012 with 134.000 tonnes). On the negative side, landfilling still represents a significant treatment option within the Luxembourg waste management system, as, in 2018, it represented 24% of the total waste treated. However, it should also be said that waste towards landfills almost halved in the period analysed, decreasing from 4.6 million tons in 2004 to 2.5 million tons in 2018.

## Figure 3-8: Total waste by waste treatment typology (Thousand tonnes)



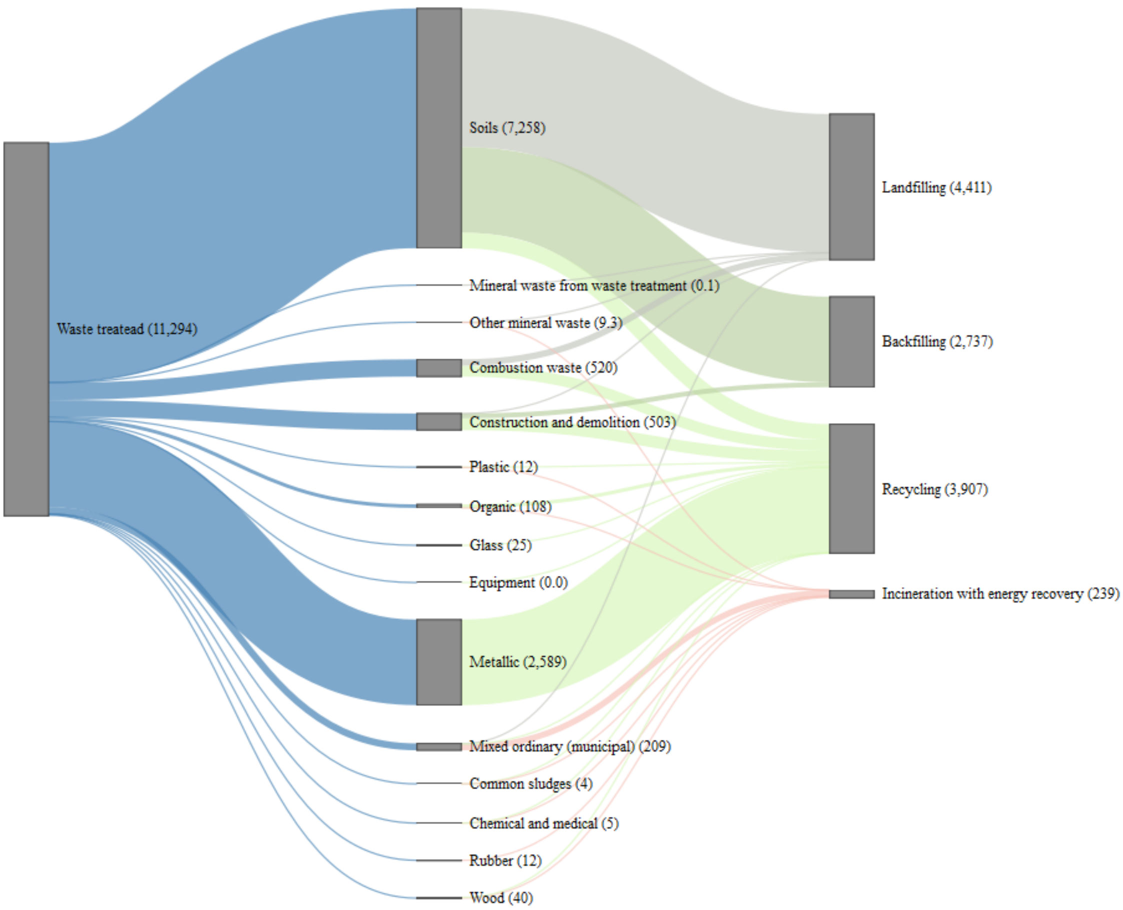

Source: own elaboration based on Eurostat "env_wastrt".

Figure 3-9 provides a detailed view of waste streams by type of waste and treatment. Red flows indicate the amount of waste directed to the less desirable treatment options (i.e. landfilling & incineration). As anticipated above, the construction sector is the biggest source of waste. About 7.5 million tonnes of rubble are excavated each year on Luxembourg's construction sites. A part of them (about 40%) is recovered and reused in areas excavated for the purpose of reclamation or safety of slopes or for engineering purposes in landscaping. However, more than half of these soils is still landfilled. Considering the fact that a huge part of Luxembourg's imports is represented by mineral materials, it might be suggested that alternative management options of excavated soils considering their treatment and recycling could strongly mitigate the country's reliance on imported materials for the construction sector. In this sector, it can be observed that some EU countries have implemented market regulatory infrastructures that enable to manage offer and demand of excavated soils also providing certified information on the quality of these materials for a quick market uptake (i.e. Grondbank[11] in Belgium).

Metallic waste, the second biggest waste stream, is entirely recycled and reused in the economy. This stream not only is constituted by the metallic waste generated in Luxembourg, but also, and above all, by the imports of scrap metals from foreign countries.

Finally, in terms of size, we can find mixed ordinary waste which is either incinerated or landfilled. The largest share of mixed ordinary waste is constituted by mixed municipal waste, bulky waste, street-cleaning waste like packaging, kitchen waste, and household equipment except separately collected fractions. Together with waste generated by construction activities, mixed ordinary waste remains one of the most problematic types of waste to manage, not only because it aggravates the problem of the lack of landfills, but also because the precious secondary material that could be embedded in it are not exploited.

## Figure 3-9: Waste flows by type of waste and treatment (Thousand tonnes, 2016).



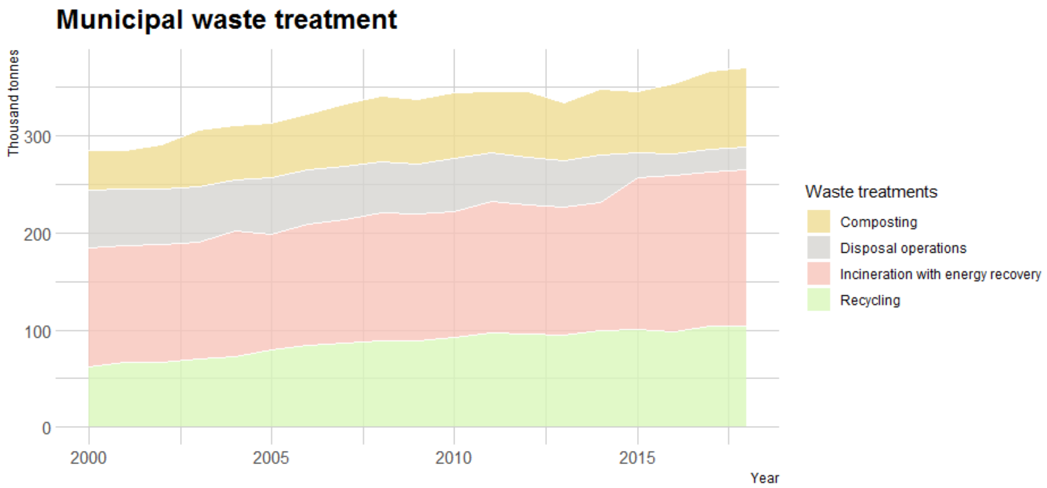

Source: own elaboration based on EUROSTAT “env_wastr”.

Distinguishing between total and municipal waste is very important, as this latter generally better reflects the quality of waste management systems. In fact, municipal waste consists of waste collected by or on behalf of municipal authorities and it consists mainly of waste generated by households, although it also includes similar waste from sources such as shops, offices and public institutions. STATEC’s database provide a

[11] https://www.grondbank.be/

further refined overview of historical trends of municipal waste treatment during the 2000-2018 period (Figure 3-10).

### Figure 3-10: Municipal waste by waste treatment typology (Thousand tonnes)



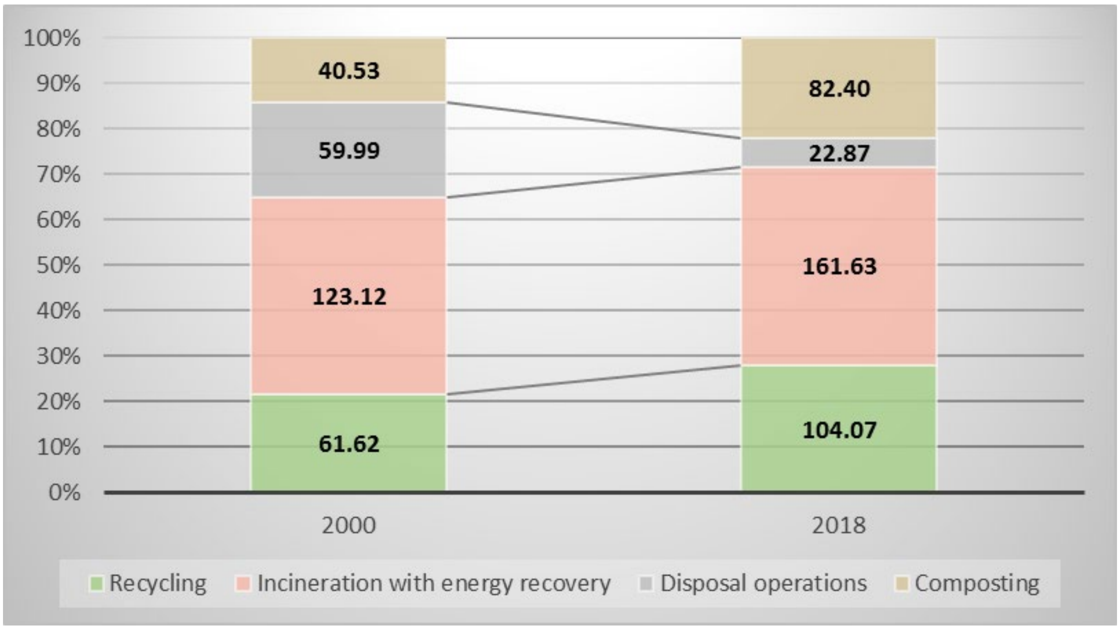

Own elaboration based on STATEC "A3300 Production and treatment of domestic waste (in 1 000 tons) 1990 – 2018".

Municipal waste treatment follows similar pattern as to the total waste, even if, obviously, it concerns a far less amount of waste (total amount of municipal waste is equal to 370.000 tonnes of waste). In 2018, incineration with energy recovery was the most common treatment option of municipal waste (44%), followed by recycling (28%) and composting (22%) (Figure 3-11). If we add up the recycled and composted waste, we could argue that Luxembourg treat 50% of municipal waste in the most efficient way and it is on track with the 2020 target of 50% recycling of municipal waste. In addition, as also observed for total waste treatment, disposal operations decreased significantly, reflecting the commitment of Luxembourg towards the progressive elimination of municipal waste landfilling. In 2018, municipal waste sent to landfills accounted for 6% of total municipal waste. This result already goes beyond the target set by the circular economy package which aims at a gradual reduction of municipal waste landfills to at least 10% of the total municipal residue by 2035.

Unlike the total amount of waste treated (

Figure 3-8), which has not changed significantly, the amount of municipal waste has been increasing over time (Figure 3-10). As mentioned above, this reflects to a large extent the steadily increase of domestic population, the main driver of municipal waste production. Perhaps, a primary thought suggested by this picture is that further efforts should be directed to higher actions within the waste management hierarchy (Potting et al., 2017), rather than options targeting the valorisation of waste. Indeed, local waste management has so far been characterised by end-of-pipe solutions, i.e. landfilling, incineration, and/or recycling. However, from an environmental perspective, prevention of waste is preferable to any kind of waste treatment and it is the only effective way to ultimately separate society's consumption from waste production. Waste prevention can occur in all life cycle phases of a product and existing legislative frameworks governing waste prevention cover a long list of different directives and regulations, e.g. REACH (Regulation (EC) No 1907/2006, 2006) and the Eco-design Directive (European Union, 2009), which aim to prevent waste in the design phases of products. Notwithstanding, the up taking of waste prevention measures is still very limited in Europe. Due to the perception of waste treatment as a completely separate policy field from waste prevention (Zacho and Mosgaard, 2016), prevention has so far had no role to play in the local waste management. Even though waste prevention has been prioritised in the European Waste Framework Directive in 2008, its integration within local waste management seems to be the exception rather than the rule (Redlingshöfer et al., 2020). Therefore, waste prevention campaigns can certainly be suitable tool in this direction, but the most critical challenge will remain how to design waste management infrastructures in ways that encourage households to produce less waste.

### Figure 3-11: Treatment of domestic waste (Thousand tonnes).



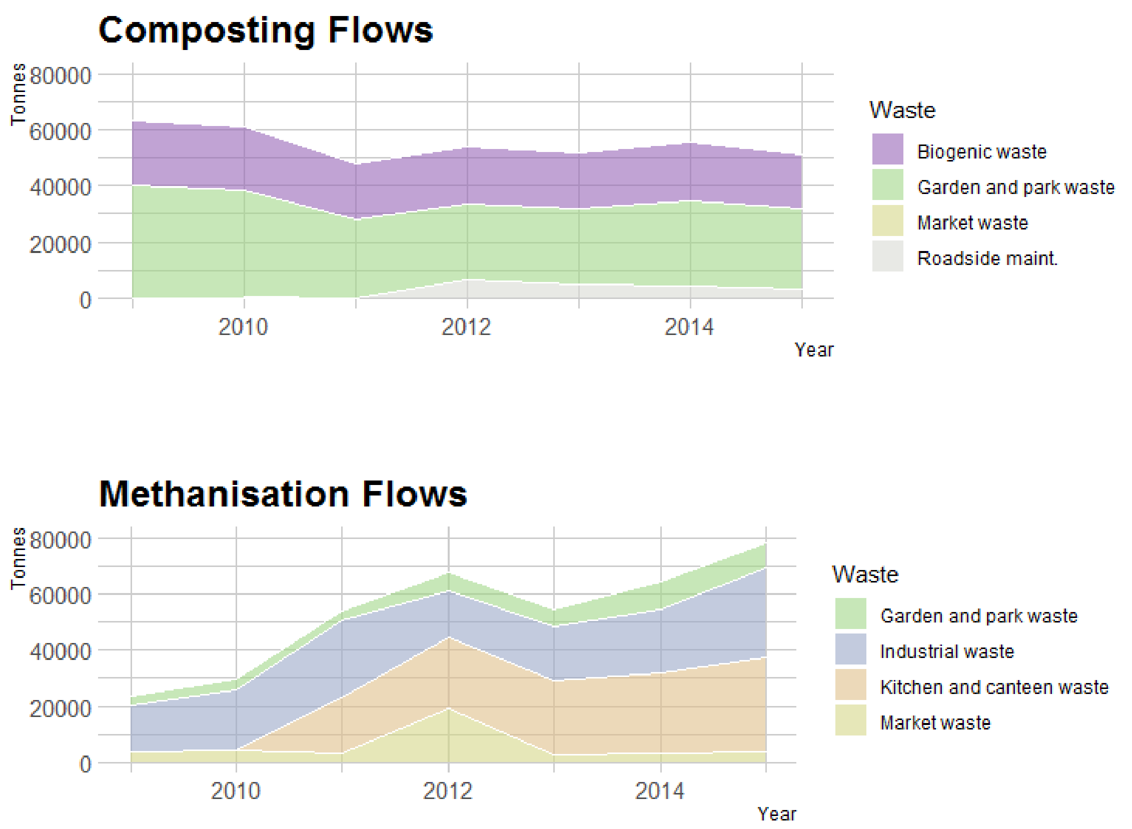

Own elaboration based on STATEC “A3300 Production and treatment of domestic waste (in 1 000 tons) 1990 – 2018”.

Actions aimed at prevention are also particularly relevant for biowaste streams, which pose several important environmental risks. On one hand, landfilling of biowaste represents one of the major sources of greenhouse gases release. On the other, if not managed properly, biowaste can contribute to eutrophication of water bodies and damage human health.

So far, the EC defines biowaste as biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants. Therefore, to a great extent, the EC definition consider biowaste as foodstuffs (including inedible parts) which become waste at any point of the food chain: (1) in primary production; (2) in processing and manufacturing; (3) in distribution; (4) in restaurants and food services; (5) in households. Consequently, large parts of agricultural biomass are excluded from its scope when they are used in the context of agriculture or forestry or for the production of energy. Likewise, animal by-products and animal carcasses are only counted as food waste when they are disposed of as waste (i.e. intended for incineration, landfill or use in a landfill biogas or composting plant).

The food waste figures generated in the CIRCTER project and presented in Map 2-7 and Map 2-8 refers to the EC definition. According to these figures, Luxembourg generated roughly 148.000 tonnes of organic waste in 2014, or 270 kg per capita, which is above the European average (210 kg/cap). On the positive side, Luxembourg was among the few populated regions that decreased the organic waste generation during the 2006-2014 period (-14%). These figures are in line with those provided in the PNGD (2018), which recorded 120.000 tonnes of biowaste generated in the same year (or 220 kg/cap). It should be noted that while the PNGD data refer to biowaste treated, the CIRCTER estimates refer to waste generated, in which it was also assumed that 25% of household waste was of organic nature. As in the case of metal waste seen above, the figures for waste generated and treated often differ from each other. Concerning biowaste, the difference between waste generated and treated is likely due to the unfeasibility to monitor effectively the waste generated by households which, to a great extent, goes to mixed municipal waste. Conversely, biowaste treatment only record the biowaste entering the treatment facilities, hence missing the amount of biowaste incinerated and/or landfilled mixed with other ordinary household wastes. Figure 3-12 shows the biowaste flows by type of treatment

**Figure 3-12: Biowaste flows by treatment option**




Own elaboration based on STATEC and PNGD.

CIRCTER and STATEC data relating to organic waste also include organic waste generated by the industrial and / or primary production activities of the food industry, which may not be considered as proper "food waste". In this context, the study carried out by ECO-Conseil in 2013/2014 and entitled "Aufkommen, Behandlung und Vermeidung von Lebensmittelabfällen im Großherzogtum Luxemburg" (2016) takes a closer look on food waste by focusing, in particular, on food processing, distribution and final consumption. According to this study, Luxembourg generated 124 kg / cap of food waste and it seems that the civil society represents the main driver of food waste production (72.5%), followed by catering, gastronomy and trade.

However, to understand the real potential savings of food waste a distinction should be made between avoidable waste (leftover meals, bulk foods such as breads, fruits and vegetables, packaged foodstuffs, etc.) from non-avoidable waste (bones, peelings of fruits and vegetables, shells egg, etc.). In this sense, the ECO-Conseil study found that 35% of households' food waste was still in its original packaging, with a small part (10%) that had not yet passed the expiry date.

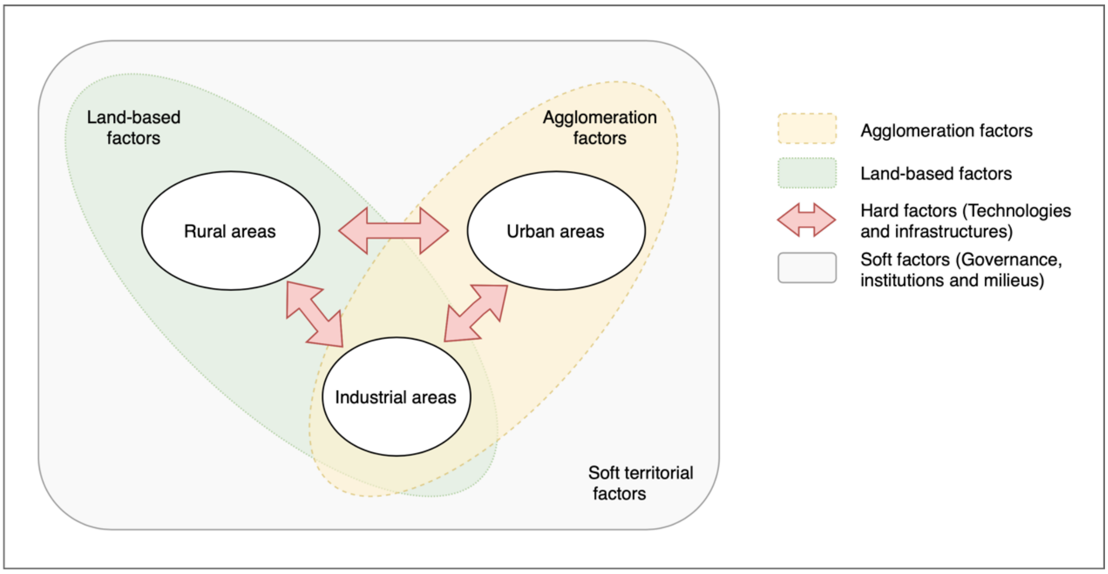
Summarising, trying to extrapolate some consistent conclusions regarding food waste patterns is very difficult due to the relatively low quality of reference data. Not surprisingly, improving the quality of data for this category has already been identified by the EC as a key-priority to monitor and support biowaste reduction. Creation of a harmonised method of measurement, improved consumption reporting practices and a system for reporting quantities of food waste generated on a biannual basis are some of the expected measures to be implemented in coming years.

For the time being, it could be argued that Luxembourg generates a more or less constant level of organic residue. The 14% reduction recorded by the CIRCTER results refers specifically to the period 2006-2014, but an in-depth analysis of the EUROSTAT and STATEC statistics does not suggest a downward trend as 2016 data is generally higher than 2014. Total organic waste generation can be estimated at about 220-270 kg per capita, while the food waste flow represents about half of the total organic waste, or 124 kg/cap. Regarding the treatment patterns, a significant increase in organic waste flows directed to methanisation facilities can be observed, while levels towards composting plants seem rather constant (Figure 3-12). Therefore, it might be argued that increasing amounts of biowaste treatment are not due to an increase in the amount of organic residues, but to the diversion of organic waste from landfill to these preferred treatment options.

# 4 Circular Economy and the territorial perspective

In this chapter, we explore the role that territorial aspects identified in CIRCTER might have in Luxembourg towards the circular economy transition, besides being potential drivers of economic competitiveness and resilience. In CIRCTER project we focused on six factors that, according to the reviewed literature, show higher relevance from a circular economy perspective. These includes (Figure 4-1): (1) land-based resources, (2) agglomeration factors, (3) accessibility conditions, (4) technical and technological capacity, (5) knowledge-related factors, and (6) governance and institutional drivers. Section 4.1 provides a brief description for each of them, while section 4.2 will expand on the potential implications for the Luxembourg territory.

**Figure 4-1: Key territorial factor towards a Circular Economy.**




Source: CIRCTER project

## 4.1 CIRCTER territorial factors

**Agglomeration factors** refer to concentration of business, consumers and/or production means required to enable certain circular economic activities. On the one hand, industrial agglomerations create the right conditions for all circular economy initiatives whenever diversity and complementarity are important enabling factors, such as for industrial symbiosis programmes (see for instance the Dunkirk case study in France (Beaurain et al., 2017; Morales and Diemer, 2019)). On the other hand, economies of scale in urban areas can also enable recovery of low-value materials that require significant volumes to ensure financial sustainability of the reclamation plants. In general, the lower the value of materials, the higher the quantities needed to enable profitable operation (Cucchiella et al., 2015; Wang et al., 2014). Economies of scale are not only important factors for recycling schemes. Urban agglomerations also create the right conditions for the development of business models that are based on product sharing, pooling and other forms of collaborative consumption (Brown et al., 2019; Cohen and Kietzmann, 2014). Frequently, urban areas are the only possible setting for profit-driven circular business models, as most of them require a certain ‘critical mass’ to become financially sustainable (Acquier et al., 2019).

**Land-based resources** emphasise the relevance of natural endowment to satisfy the growing demand for raw materials and biomass feedstock for a circular economy. Unlike inert materials that need to be recovered and used in closed-loops, biotic materials shall be used in cascades. This refers to the efficient utilisation of organic resources by using residues and recycled materials sequentially to extend total biomass availability within a given system. In general, circular economy frameworks emphasize the perspective of sustainable management of renewables feedstocks (e.g. farming, fishing, harvesting etc.), thus linking land-based factors with rural areas, where the greater availability of land allows such activities. However, this is only part of the story, as urban areas also play, indirectly, a key-role to close biotic loops. First of all, cities produce the largest amount of food waste. This means that they can take an active role in optimising consumption of food, reducing in the first instance the organic waste and re-directing the residuals to soil regeneration treatments. Second, available land is often the most valuable resource in cities. In general, cities depend on peripheric areas for the procurement of resources and assimilation of waste. The allocation of land in cities for ecosystem services for production (e.g. urban agriculture), to tackle the degradation of natural capital (e.g. carbon dioxide emissions using urban forestry) and environmental hazards (e.g. to alleviate flooding using nature-based solutions) could potentially help reduce the consumption of inland resources and regenerate the urban ecosystem (Williams, 2019).

Agglomeration and land-based factors mostly define the right framework conditions for specific circular strategies. Still they are not the only factors enabling successful transition towards circular system. Closing material loops also require good access to secondary materials and by-products by economic actors. **Accessibility** to used products and secondary materials can greatly affect operational costs of firms adopting circular business models (Holgado and Aminoff, 2019) or participating in industrial symbiosis schemes (Domenech et al., 2019). In this sense, infrastructure enables the transportation and re-allocation of stocks in an efficient way. In general, areas located close to transportation hubs, like airports, ports, railway stations, and/or having in place effective intermodal transportation systems and logistic hubs can be significantly advantaged when it comes to triggering the economies of scale related to e.g. the processing of secondary raw materials, e.g. low-value waste collection recycling (Malinauskaite et al., 2017). This infrastructure is also required for the establishment of circular business models based on e.g. reverse logistics and take-back programmes (Dhakal et al., 2016).

Next to accessibility**, knowledge-base** and **technology capacity** factors also boost the development of circular economy in various ways. Technical knowledge, skills and information, including access to guidance and capacity to assemble and absorb knowledge are equally relevant at business, institutional and community levels. In the private sector, these factors become crucial for the development of more sustainable products and services through strategies such as eco-design, life-cycle-thinking and the adoption of circular business models. Equally, the role of emerging technologies triggering epochal shifts in industrial systems is widely recognised, particularly for digital technologies (Pagoropoulos et al., 2017) and industry 4.0 (Nascimento et al., 2019). Technologies enable the implementation of circular economy processes not only along the value chain (e.g. cleaner production and eco-design) but also have a critical role for unlocking the market for secondary low-value material streams (Jawahir and Bradley, 2016). However, circular solutions and technologies like refurbishment and remanufacturing often compete with traditional, often cheaper, alternatives (Korhonen et al., 2018). Moreover, technologies may also create path dependences and lock-in in specific areas (Kalkuhl et al., 2012; Wilts and von Gries, 2015), including the bioeconomy (Marsden and Farioli, 2015).

Last but not least, **governance and institutional factors** contribute to create the necessary conditions for circular economy activities to root and materialise in concrete actions (Kanda et al., 2019). Governance and institutional arrangements not only promote circular economy principles, but also favour the establishment of other factors, such as knowledge diffusion and increased collaboration between firms (Niesten et al., 2017). Cultural and symbolic aspects of social elements, such as values, norms, cognitive repertoires, are also viewed as strategic assets affecting innovation because of their capacity to enhance small firms' action and to provide opportunities to compete in the knowledge economy (Fernández-Esquinas et al., 2017). Localised interactions between societal (value attitude, life-style, perceptions), institutional (regional policy context) and market components (networks, cooperation, etc.) have the capability to relate physical resources with local actors, facilitating the circulation of information and agent coordination within a region (Capello et al., 2007). Such networks and connections can enable and promote circular economy transformations, as the latter require stronger collaboration between companies throughout the entire value chain (Lahti et al., 2018).

## 4.2 Luxembourg's territorial implications

As claimed several times across this report, Luxembourg presents a unique context in the European panorama. Unlike most of the European economies that entered a stagnant if not recessionary phase during the economic and financial crisis, Luxembourg has been able to withstand a stable and steady economic expansion over the past decade. On one hand, this has been mainly possible thanks to its economic diversification and the strong specialisation in service-based sectors, among which the financial sectors outstand. On the other hand, its strategic geographical position not only ensured a constant supply of workforce from neighbouring regions, but also placed Luxembourg as one of the main logistical hubs in Europe.

Agglomeration, knowledge and technology might be seen as the leading and reinforcing territorial factors currently supporting the Luxembourg transition towards a circular economy. Luxembourg already claimed, as one of its main strategic goal, to be “A Knowledge Capital and Testing Ground for the Circular Economy”. This objective is well reflected in CIRCTER results that positions Luxembourg as one of the cutting-edge European regions in terms of circular business model already installed in the domestic territory. Luxembourg counts with some of the most advanced manufacturing sectors, especially steel manufacturing, besides being, together with the Greater Region, a reference platform for knowledge creation and sharing on R&D materials. The technological and knowledge endowments of Luxembourg have been extensively analysed in previous studies (EPEA, 2014). Therefore, we will focus here on the remaining territorial factors, elaborating the results of present analysis along with the insights developed in the CIRCTER project.

### 4.2.1 Land-based factors

From a circular perspective, land availability in Luxembourg might be considered as the untapped most valuable resource. The remarkable economic and demographic development of this region generated very high needs in terms of jobs and housing. But also, it translated in substantial accumulations of natural resources in buildings, infrastructures, products and waste deposits. As a result, land available for construction is limited and extremely expensive. In addition, hedge cities like Luxembourg very often suffer from speculation in the real estate sector, which eventually further exacerbates the issue of land shortage (Glumac and Decoville, 2020). Of course, scarcity increase the value of land and properties. But it also can hold back the setting up of lower-value activities (Williams, 2019). In general, circular economy activities such as recycling industry, regenerative urban forestry, urban farming, could be considered to be low-value activities as the added value per produced unit might be considered rather low. These activities are essential for the local production of resources, for repairing products and waste recycling. To some extent, such local activities could help mitigate the significant reliance of Luxembourg on import of raw materials. Therefore, land which remains vacant because of difficulties with land assembly or simply due to speculation (i.e. brownfields) is considered as an unexploited valuable resource for the deployment of circular economy related activities.

Despite the fact that the steel sector is a strong player in today’s national economy, Luxembourg’s historical steel industry, similarly to other EU steel regions, has been considerably modified by either the fading out of blast furnace technology with the closing of iron mines and industrial plants and the progressive deployment/specialization of Electric Arc Furnace (EAF) technology fed with scrap metal as input material. The transition from one industrial technology to the next generation EAF technology has left behind large industrial abandoned areas, i.e. brownfields. Glumac and Decoville (2020) assert that brownfield sites represent 16% of all the land available for building in Luxembourg according to local development plans (i.e. 537 ha). In the spirit of a circular economy, industrial areas in transition and deindustrialisation deserve particular attention. Abandoned industrial installations could be dismantled and either sold for reuse or recycled and industrial sites could be reused. Vacant buildings could also be adapted to new circular industrial and non-industrial uses, or be transformed into public spaces, thereby contributing to regenerative spatial and urban planning. Returning abandoned land and buildings back into the economic cycle can be seen as an effective way to reduce urban sprawl and its environmental impacts and to keep neighbourhoods occupied and vital. It is therefore considered to be an attractive alternative to new construction or to using non-sealed soil in terms of a circular economy.

Land-use patterns and urban form can also affect resource consumption. In the case of Luxembourg, they represent critical factors for moderating the use of energy in transport and buildings. Indeed, the massive influx of cross-borders workers not only contributes to the saturation of road and rail network, but it also contributes to fossil fuel depletion and thereby carbon dioxide emissions. Therefore, zoning development should be avoided in favour of mixed-used planning. This latter localises trips (Nimax, 2018) and can also enable industrial symbiosis configurations (Pandis Iveroth, 2014).

Brownfield redevelopment and mixed-used planning can also combine, resulting in multiple win-win situations. Without looking outside the Luxembourg territory, the pioneering case of the Belval project represents an excellent case study in which the various issues mentioned above such as the recycling of contaminated land, uncontrolled urban sprawl and high house prices have been addressed in an integrated and effective way (Glumac and Decoville, 2020).

### 4.2.2 Agglomeration factors

#### The end-pipe of circular economy: Urban mining

Luxembourg is one of the European regions best positioned in terms of urban and industrial agglomeration factors. Besides being one of the most important financial hubs worldwide and having an economy very specialised in service-based activities, Luxembourg also has a cutting-edge manufacturing industry which already relies heavily on the reuse of secondary raw materials. These latter are core to the survival of some of Luxembourg's leading primary industries, in particular steel manufacturing. While it is a competitive priority to sharpen and scale up Luxembourg's capacities for reusing secondary material, it should also be noted that these are mainly imported from foreign countries. Complementary efforts should also be sought to improve the circular loop of secondary material within the domestic territory. Obviously, domestic supply is not enough to fulfil the Luxembourg manufacturing demand for secondary materials, but reusing in-situ stock of materials (i.e. urban mining) might be an important lever to increase the resilience of the economy in the long run.

Indeed, in a time when resources are becoming increasingly scarce, the reservoir of technospheric resources embedded in existing infrastructures could offer an opportunity for more sustainable development, or at least provide an alternative to virgin production and recycling of annual waste flows. Luxembourg has a limited access to natural resources due to its limited geographical size. But it benefits from a very dense urban configuration and transport infrastructure. These represent genuine urban mines that can be compared to existing natural reserves (Cossu and Williams, 2015). Cities are at the point of becoming the mines of the future – playing both the role of the consumer and the supplier of (their own) resources. Urban mining will help cities to expand in more sustainable ways, by reducing the need for primary resources and by avoiding at the same time the environmental impacts associated with the production of such resources. In addition, the utilization of domestic secondary resources (either directly or in a processed form) would decrease not only the input required from primary resources but also the required space for landfilling of these materials at the end of the life-cycle. This is especially critical for the Luxemburg construction sector, which on one hand relies almost entirely on import of construction and building materials, on the other, it generates huge quantities of waste (i.e. rubble) for which landfilling capacities are running out in the country[12].

Despite construction residues represent the biggest waste streams in Luxembourg metabolism, they are not the only type of waste not efficiently exploited. Currently, roughly half of the municipal waste produced in Luxembourg still appears to be landfilled, incinerated or exported to neighbourhoods' countries (predominantly Germany and Belgium) to be recycled or incinerated. Although 50% recycling rate constitutes the EU 2020 target, it does not represent a satisfactory return for Luxembourg, which has recorded such recycling rate since 2010. Most surprisingly, according to the "Plan National de Gestion des Dechets et des Ressources" (2018), Luxembourg city features the lowest recycling rate across Luxembourg municipalities (<40%).

The effective collection and sorting of municipal waste is often more complex than the management of industrial waste, where, in general, the same companies are responsible for the collection and delivery of their waste to the respective treatment plants. Effective municipal waste management requires both, citizenship commitment and a well-designed collection scheme in which downstream infrastructure for pre-treatment, sorting and recovery must be aligned with upstream means for waste collection.

Likewise, it is important to avoid the "lock-in" trap of incineration facilities (Corvellec et al., 2013). These infrastructures require a stable amount of incoming material to be incinerated to be profitable. However, they represent a less valuable waste treatment option compared to reusing and/or recycling. Obviously, existing incineration plants should operate at complete capacity in order to maximise capital invested. However, as

[12] https://today.rtl.lu/news/luxembourg/a/1587629.html

municipal waste is likely to grow in Luxembourg due to population expansion, the planning of future installations should be discouraged as it would run the risk of preventing the entry into the market of more efficient waste treatment technologies.

Thanks to high concentrations of built environment, capital, and talent, and also favoured by incoming commuter workers who further contribute to leverage economies of scale, Luxembourg is well placed to achieve the critical masses for harvesting the urban waste in an economically efficient way. Furthermore, if we consider the economic structure of Luxembourg, mostly specialised in advanced manufacturing and IT technology, the harvesting of urban waste might be especially strategic for the recovering of Critical Raw Material (CRM), in particular e-waste. According to ProSum EU project[13], Luxembourg exhibits the highest figures in batteries[14] and vehicles weight per capita across European countries, i.e. 40 kg/cap and 1000 kg/cap respectively. These materials placed on the market and adding to the stock of used and hibernated products, become waste generated at some point. Here, the good news for recyclers specialised in this treatment category is that the precious metal content will continue to increase in the coming years, primarily due to consumption behavioural patterns. The bad news is that more than 40% WEEE generated in Luxembourg is still not reported by the official compliance systems, or in other words, their fate is to a large extent unknown.

## The production side of circular economy: Circular Business Models

Thanks to its diversified economy, Luxembourg is also well positioned to embark on several CBMs. As the sectoral perspectives showed, several companies on the national territory have already integrated and operationalised CE principles. The number of businesses supporting long-life design products and eco-design for repair for refurbishment and remanufacturing are among the highest across European regions. Similar findings were found in the EPEA study (2014), which identified more than 20 commercial planning and research activities happening across Luxembourg with the potential to accelerate and benefit from circularity. Similarly, business models focusing on the exploitation of residual values of products and secondary material already play a key-role in Luxembourgish economy. A prime example is AcelorMittal, which did of steel renting and take-back programs a strategic feature of its business model.

While the manufacturing sector is on its way to achieve a more circular loop, the construction sector seems to lag behind. Despite the sector presents several example of good practices in which construction products are designed for circularity (e.g. Ecoparc Windhof, parking infrastructure for the Mobility Innovation Campus in Bissen.), the statistics indicates that rubble generated in construction and demolition works are still among the main concerns for Luxembourg, as landfilling capacities for such kind of waste are collapsing. Considering that landfilling should not be anymore an option in the long term, further efforts should be put on both waste generation prevention measures together with better treatment and reuse capacities. In this sense, innovations in the construction sectors are strongly needed, ranging from eco-design innovation (i.e. modular eco-design) and also including better practices in demolition works, i.e. smart technologies for waste separation on-site. In this sense, a good example is provided by the city of Paris, which is developing a deconstruction/demolition framework agreement that establishes a deconstruction methodology for construction waste management (OECD, 2020). Through deconstruction, materials and components with reusability capability are disassembled and are further used in another project. Therefore, valuable materials and components will remain in the market value chain for a more extended period of time in order to fulfil their expected service life (Akbarieh et al., 2020). Accordingly, construction tenders might include selection criteria such as: sorting organisation internally on site; transport of waste to a recycling platform, traceability of the disposal of construction waste; the rate of recovery of construction waste specifying the nature of waste, the sectors and suppliers.

[13] http://www.prosumproject.eu/

[14] The ProSUM project distinguishes seven categories of batteries: the primary batteries based on zinc and on lithium, the rechargeable batteries based on lithium, lead, nickel metal hydride (NiMH) and nickel-cadmium (NiCd) and other batteries

### The consumption side of circular economy: changing behavioral patterns

People are at the centre of a cultural shift towards new business and governance models within a circular economy. Changing the practices and consumption habits of those living in cities will be critical to the delivery of resource decoupling. More specifically, if citizens do not ‘buy into’ consuming circular products (e.g. recycled goods, renewable energy etc.) and services (e.g. renting, leasing, sharing etc.) or adopt circular practices (e.g. repairing or upcycling goods, composting organic waste), then a circular society is undeliverable.

According with the CIRCTER sectoral analysis, the circular business models aimed at changing consumption patterns by promoting sufficiency and functional utility rather than the mere possession of goods are perhaps the most difficult to implement in the Luxembourg socioeconomic fabric. However, reuse and repair are important levers for waste prevention and can also boost the social economy, especially in denser areas such as Luxembourg city, where urban agglomerations make social exchange easier. Having a significant job creation potential, they should be at the core of any local and regional initiative to favour the shift towards circularity in socially inclusive manner. In this context, Interreg Europe programs can be a critical tool to support regional and local governments in developing better policy. Several Interreg projects such as SUBTRACT, RaiSE and 2LIFES, showcased various good practices on how reusing and repairing are key for saving resources and for fostering waste prevention.

Likewise, the current Interreg Europe programme also provides support to partners which intend to work together on the challenge of tackling food waste. A successful initiative is constituted by the Last-Minute Market (LMM). Started as a spin-off from the University of Bologna (Italy), LMM today is an entrepreneurial society working at national level in Italy focused on developing local projects for recovery of unsold goods in favour of non-profit organisations. LMM supports the creation of a solidarity network and facilitates the contact between non-profit institutions and businesses.

Public-private partnerships also need to be formed, so that the public sector can assign specific tasks to social enterprises, providing revenue streams for sustaining their activities. Social criteria should be included in public tendering with the view to give recognition to social enterprises for creating positive social impact through their services.

### 4.2.3 Accessibility: reverse logistic & nearshoring

Nestled between France, Belgium and Germany, Luxembourg has always been a transport logistic hub for industry and not only. Its excellent geographic location and multicultural capabilities permit more than 50 million tonnes per year transported through its hubs (EPEA, 2014). The excellent transport infrastructure already in place makes of Luxembourg one of the best testbeds for reverse logistic management in Europe. However, on the downside, vast logistic infrastructure also means traffic congestion, noise, land and environmental degradation, all items increasingly affecting the quality of life of Luxembourg citizens. Hence, it is important that future reverse logistics projects maximize the capacities of the existing infrastructures, considering only in a second term and after careful analysis the further extension of the transport network.

Next to reverse logistic, and potentially a mitigating measure of traffic jam and environmental degradation might be the near-shoring concept, which refers to the relocation of production close to the point of final product use. Near-shoring is significant for circular economies because it brings together suppliers and users/customers and enables collaborations in circular business models. Nowadays, near-shoring or “re-shoring[15]” business strategies are experiencing a renewed interest mainly as a result of the current COVID-19 crisis, which has highlighted the vulnerabilities of global supply chains. Existing studies recognise the importance of near-shoring activities, especially R&D and high-tech activities, as they might be critical levers for the reinforcement of Luxembourgish economy and thus, jobs creation (EPEA, 2014). However, just as near-shoring strategies make sense for the flows of production and consumption of materials, the same is true for the relative movements of the workforce. In this sense, strategic territorial planning should not only worry about the localisation of new economic activities, but also to devise affordable and liveable places for

[15] *Re-shoring* specifically refers to bringing offshore manufacturing and services back from – generally – lower-wage foreign countries to the domestic territory.

the people working in such activities. Focusing only on the economic side of near-shoring strategy might further exacerbate the on-going Luxembourg issues related with the significant cross-border commuters flows.

### 4.2.4 Governance

Governance is a critical catalyst to effectively transition towards circular economy. First of all, governments at various levels should gradually converge towards the development and implementation of a shared long-term strategy for a circular economy. As such, understanding how roles and responsibilities for designing, implementing and monitoring circular economy initiatives are allocated across national, municipal and local governments are critical to identify potential gaps. Second, it has the responsibility to bring the relevant stakeholders together, including citizenships, and mediate between their respective stakes.

The level of analysis and type of data employed in CIRCTER project do not allow to properly distinguish between different governance contexts, especially concerning the Luxembourg territory that is characterised by a unique region. However, according to the PNGD (2018), it seems that there is still a certain level of inhomogeneity between the different municipalities across a number of factors, including waste collection system, taxes and application of “polluters pay” principle. The cooperation and coordination of municipalities, unions and the various systems should be further consolidated and strengthened. Better coordination of the different systems not only would increase the collection of different fractions of waste and optimizes their use, but it also would allow citizens to have a homogeneous and clear public image. Empirical evidence showed that having a separate collection system for biowaste reduces significantly the amount of organic residual generated by households. However, only 67.1% of Luxembourg population were connected to such system in 2016 (PNGD, 2018).

Local government has the key role of coordinating and facilitating partnerships with private entities. In this sense, Luxembourg has a long tradition for its business-minded policies and its ability to align stakeholders across sectors. This is an important advantage that not only permits the country to adjust quickly to shifts in marketplace conditions, but also it facilitates the kind of experimentation the circular economy calls for.

# 5 Policy perspectives

The CIRCTER project provided, in a synthetic way, an overview and analysis of several types of circular economy policies and initiatives, making a direct link between policy actions and territorial configurations and/or factors. Based on Luxembourg's evidence, this section highlights key messages for the potential leverages of circular economy in Luxembourg from a territorial perspective.

First of all, it should be emphasized that the concept of circular economy applied to a territory goes far beyond the search for circular loops of materials and resources, as these latter often remain tied to a reduced economic perspective. Territories are complex ecosystems that require critical consideration during the development of circular strategies. As an example, land and infrastructure are important resources which should be integrated into the conceptualisation of a circular system. Similarly, the term "resources" not necessarily has to be interpreted as physical flows of materials. From a territorial perspective, human capital is also a resource which can contribute to generating positive impacts when their activities are better steered towards synergetic goals under a coherent integrated strategy. The significant cross-border commuter flows that characterize Luxembourg provides the country with a critical source of workforce that is key to sustain the country's economy either in the secondary or tertiary sectors. Despite the fact that frontiers within EU have disappeared, these circumstances though do drag a series of negative consequences like increased commuting time, traffic jam, accidents as well as their associated environmental impacts (e.g. pollution, noise, land use by transport infrastructures, etc.). A derived further consequence of the above may consist in a reduced productivity. Therefore, the effectiveness of circular systems should be fostered by first revealing, and second designing out negative externalities related to resource flows.

As a way forward and as an example, we may indicate that **purposeful design of the built environment** can strongly facilitate CE practices. The promotion of mixed-used zones, or even better, the regeneration of abandoned land, i.e. brownfields through industrial co-location, might represent for Luxembourg a high-level opportunity of aspiring to closed-loop systems. To this end, it is above all important to mitigate the speculation of land and housing, which disconnects them from their social and environmental functions. Therefore, it is critical to start building a dialogue for institutional cooperation that perhaps has been missing to date (Glumac and Decoville, 2020).

As it seems that Luxembourg represents very different circularity performance scores across municipalities (i.e. different recycling rates, different understandings and implementation of polluter-pays-principle), it might be suggested that **institutional cooperation** should be enhanced across local policymakers also in order to avoid eventual trade-offs across the existing urban centers and municipalities at a national scale. Divergence of those factors mentioned above, along with different tax rates on businesses, ultimately hampers the establishment of more coherent circular transitions based on common incentive frameworks. Ideally, the people, whether they live in or use space, should also be included in decision making procedures to greater extent. Innovative participative procedures for integrating citizen in local decision making are developing across Europe and could serve as inspiration.

The finding from Luxembourg analysis revealed that considerable efforts at the local level to improve resource management and recycling practices have been undertaken. Despite this, municipal waste generation continues to increase, while imports across most of material categories are steadily increasing. These patterns indicate that effective measures towards circularity should target the root of the problem (i.e. waste generation) rather than mainly treating the problem once it has arisen (i.e. waste management). Hence, reducing the total amounts of waste ought to be the primary objective. This would also avoid the risk of investing in waste infrastructure, which may not be necessary if prevention measures are adopted in the first place (Zacho and Mosgaard, 2016). For this reason, Luxembourg should consider what could be done to prevent waste before committing economically to long-term investments in waste treatment infrastructure. In this sense, municipal waste prevention initiatives might be addressed from two perspectives: (1) targeting retail and industry and (2) targeting households.

For the first, several overarching strategies might help to mitigate the amount of waste generation, these may consist in the promoting reuse, repair and remanufacturing of products that have completed their first life cycle. To some extent, such strategies are capable to boost the creation of new business models linked with the generation of local employment and second hand markets for consumers with lower incomes. Complementary to the above, **Urban Mining, hence,** the process of reclaiming raw materials from spent products, buildings and waste could be further explored. . Luxembourg is a growing society, and just as the demand for materials will continue to grow, so will the outflows of materials. Urban Mining aims to manage and use these materials as a source of raw material supply, utilizing not only the waste of today but also anticipating and capturing the value contained in the waste of tomorrow. Therefore, urban mining should not only be an important part of a Circular Economy strategy, but it also represents a strategic goal for Luxembourg economy as it provides a degree of independence from natural resources, increasing supply security. This could apply to some critical raw materials (CRM), whose demand, and thereby prices, are expected to grow exponentially in the coming years (European Commission, 2018). The CRM value embedded in existing products is generally much lower than the value of the product they would enable. This follows from the challenges – from organizational to technological to economic – facing the recovery of raw materials from a highly diverse and highly complex resource base. Therefore, policy initiatives regarding the correct design of products in those sectors in which Luxembourg is producing its own products should be developed further. For imported goods, a longer term perspective should be adopted to require from international suppliers of products some minimum eco-design standards that would enable more cost effective reuse, repair, remanufacturing and recycling processes. The CIRCTER project and the present study can only offer a limited guidance in this respect as only very aggregated material flows were considered. In order to support a good decision-making, the effort of gathering and analysing data and knowledge on (critical) raw materials needs to be continued and even intensified. Material flows should be analysed at more granular detail in order to be better understood. Similarly, the supply chains and technological developments (e.g. emerging applications, new processes) will have to be monitored in order to identify strategic (critical) material flows to be addressed. All these actions will need sectorial focuses but will also benefit from synergies across sectors. Industry has an important role to play as both designer and provider of products as well as collector and recycler. Recognizing the need to consider repair and disassembly as much as possible as part of the design process, and conveying this information together with the products, would not only encourage more widespread repair & refurbishing but also contribute to allocating end-of-life products to the proper recycling routes, allowing for the maximal recovery of raw materials. The Raw Material Information System (RMIS[16]) could be very instrumental in keeping this knowledge base up-to-dates.

Finally, as the EPEA study also points out, the second important mechanism fostering waste prevention consists in a **widespread behavioural change.** Currently, this is mainly supported by communication programmes and awareness campaign oriented to households consumption attitudes. However, there is increasing evidence that relegating waste prevention as merely a question of individuals making better choice is often a too simplistic approach. Rather, it seems necessary a need to change the structures in which practices related to waste prevention occur, i.e. waste management infrastructures should be designed in ways that encourage **citizenships to actively participate in local recycling, reusing and repairing activities**. Circular economy initiatives, such as repair cafés, can be considered front-runner in this aspect, as waste prevention and reuse are generally beyond the traditional obligations of local waste management actors and, therefore, little analysed (Zacho and Mosgaard, 2016). Therefore, local government planning should foresee strategic locations to integrate CE practices into the built environment, hence designing spaces to make circular resource management visible and accessible.

[16] https://rmis.jrc.ec.europa.eu/

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