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Circular economy indicators for person mobility and transport

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Circular economy indicators for person mobility and transport

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Summary

In this report the set of indicators composing the mobility system is presented, as part of the CE monitor developed in the policy research centre. The indicators show that **the current state of the mobility system is far from circular, and its evolution seems to continue rather in the linear direction**. Huge amounts of materials are involved with the mobility system, and these amounts have increased over time, with vehicles growing in amounts, and these being used less intensively and efficiently. There is no substantial evolution in the modal shift towards public transport or bicycles, which take less materials versus persons transported. The popularity of car sharing has strongly increased over the last few years, but it is not possible to conclude anything yet on its impact on car production and use. New cars entering the market do not become lighter, although their environmental performance is steadily improving. Large amounts of fuels are consumed. Valorization of used tyres is mainly downcycling, with decreasing shares of reuse and reprofiling. Valorization of EoL cars via official demolition has improved a lot: amounts of materials landfilled or incinerated have become minimal, and reuse has increased. Cars tend to be kept in use longer, but it is not clear yet whether the mileage at end of life has increased as well, neither to which extent this balances with environmental impacts.

The compilation of this mobility monitor has been the first elaboration of the concept of systems fulfilling societal needs with indicators. While this concept takes a footprint perspective as a basis, with a lot of attention for consumption, a number of indicators were included in order to reflect the roles of the actors producing goods and services, as was the case for instance for freight transport. The ambition to incorporate micro indicators was only met to a limited extent in the monitor, but the focus on product groups and on the life cycle of products (the so-called 'meso' level as denoted before) allows to measure circular economy in a more direct way as progress will be picked up in an early stage.

With respect to data gathering, it appeared that especially cars are relatively easy to track for monitoring, with a lot of data openly available. Still, a number of data did not become accessible within the scope of this work, like use data in car sharing, and total amounts, environmental performance and mileage of EoL cars, and more detailed data on car production. Further action is to be undertaken to gather such data, in order to track progress towards the CE at an even higher level of detail. Indicators on environmental impacts have been limited to greenhouse gas emissions, but in future versions of the monitor also other impact categories will need to be added. Furthermore, indicators focusing on the materials in low-emission vehicles will need to be included.

It was revealed that the data displayed a large diversity and were spread over a large range of sources. Moreover, stakeholder interaction has been essential to obtain the current results. For the future maintenance and development of the CE monitor, it will be important to consider a data governance that enables bringing together and manage data from different stakeholders in a safe and collaborative way.

Samenvatting

In dit rapport wordt de indicatorenset van het systeem mobiliteit voorgesteld, als onderdeel van de CE monitor in ontwikkeling in het Steunpunt. De indicatoren tonen dat **de huidige staat van het mobiliteitssysteem verre van circulair is, en dat de evolutie zich veeleer verderzet in lineaire richting**. Er zitten enorme hoeveelheden materialen in het mobiliteitssysteem, en deze hoeveelheden zijn toegenomen doorheen de tijd, met groeiende aantallen voertuigen die minder intensief en efficiënt gebruikt worden. Er is geen duidelijke evolutie in de modal shift naar openbaar vervoer of fietsen, waarin de verhouding materialen versus personen lager is. De populariteit van autodelen is de laatste jaren sterk toegenomen, maar het is nog niet mogelijk om iets te concluderen over de impact op productie en gebruik van wagens. Nieuwe wagens die op de markt komen zijn niet lichter, maar de milieuprestaties ervan verbeteren gestaag. Heel grote hoeveelheden brandstoffen worden verbruikt. Valorisatie van gebruikte banden komt hoofdzakelijk neer op downcycling, met afnemende aandelen hergebruik en loopvlakvernieuwing. Valorizatie van gesloopte wagens via de officiële weg is sterk verbeterd: de hoeveelheden verbrand of gestort materiaal zijn inmiddels minimaal, en er is meer hergebruik. Wagens blijven langer in gebruik, maar het is nog niet duidelijk of de kilometerstand bij sloop ook toegenomen is, noch in welke mate zich dit verhoudt tot milieu-impact.

Het invullen van deze mobiliteitsmonitor met indicatoren is de eerste uitwerking van het concept van behoeftesystemen. Terwijl dit concept vertrekt van een consumptieperspectief, zijn er ook een aantal indicatoren opgenomen die de rollen van actoren die goederen en diensten produceren weergeven, zoals bijvoorbeeld over vrachtvervoer. De ambitie om micro-indicatoren op te nemen is slechts beperkt gerealiseerd, maar de focus op productgroepen en op de levenscyclus van producten (het zogenoemde ‘meso’-niveau uit eerder werk) laat toe om de circulaire economie meer direct te meten omdat voortgang in een vroeg stadium opgepikt zal worden.

Wat betreft het verzamelen van data bleek dat wagens relatief makkelijk te monitoren zijn, omdat veel data openbaar beschikbaar zijn. Toch bestaan er nog meer data buiten dit werk om, zoals gebruiksdata in autodelen en totale hoeveelheden, milieuprestaties en kilometerstanden van gesloopte wagens, en meer gedetailleerde data over productie van wagens. Verdere actie dient ondernomen te worden om dergelijke data te verzamelen, om de voortgang naar de CE op een dieper niveau van detail te kunnen opvolgen. Indicatoren over milieu-impacten werden beperkt tot broeikasgasuitstoot, maar in toekomstige versies van de monitor moeten ook andere impactcategorieën toegevoegd worden. Verder moet er plaats komen voor indicatoren met focus op de materialen in lage-emissievoertuigen.

In dit werk viel het op dat de data erg divers zijn en over een hele reeks databronnen verspreid zaten. Daarnaast was interactie met stakeholders essentieel om tot de huidige resultaten te komen. Voor toekomstig onderhoud en ontwikkeling van de CE monitor zal het belangrijk zijn om na te denken over een databeheer dat mogelijk maakt om data van verschillende stakeholders op een veilige en collaboratieve manier samen te brengen en te gebruiken.

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Circular economy indicators for person mobility and transport

1. Introduction

In the research program of the Policy Research Centre Circular Economy (Steunpunt Circulaire Economie), which has taken off in 2017, one of the key deliverables is the framework for a circular economy (CE) monitor for Flanders by 2021. In the first stage of this research a conceptual underpinning of this monitor has been developed, in order to collect indicators reflecting the CE transition in terms of results and effects. The main building blocks within this concept were the so-called systems to fulfill societal needs [Alaerts et al., 2019a; Alaerts et al., 2019b]. In these systems material consumption and impacts are to be monitored in between the society-wide level of macro indicators and the micro level of indicators focusing on products. The idea is that in this way a more direct feedback to policy will be delivered, as the combination of indicators from different levels will allow the effects of policy and innovation to be picked up earlier at the level of products and at the same time reveal how these effects add up and start to affect society at a broader level. The systems to fulfill societal needs can be seen to coincide with major consumption domains. For monitoring CE these have been determined as mobility, housing, nutrition&water and consumption goods. Together they determine ca. 90% of the material and carbon footprints, as calculated via input/output analysis [Raes et al., 2020; Vercalsteren et al., 2017; Christis et al., 2019a].

In previous work, the mobility system has been preliminary elaborated in order to make the concept of the monitor more tangible, by showing how it could eventually materialize in indicators. The choice to start with this system was based on the outcome of the discussions at a stakeholder workshop held in the pathway to develop the monitor [Alaerts et al., 2019a; Alaerts et al., 2019b]. The amount of available data for the mobility system was estimated to be relatively large and the set of preliminary ideas on indicator development was the most advanced among the need systems discussed at the workshop. Hence the elaboration of the mobility system seemed a logical starting point for building up the monitor, also with respect to gaining practical experience in applying the concept of systems to fulfill societal needs and discovering challenges and bottlenecks in this process without being bothered too early in this process with issues of data availability. The preliminary exercise of gathering data and composing indicators that has been published before has now been completed by thoroughly screening and checking relevant data sources, evaluating their potential to build indicators and interpreting the obtained indicator scores. In this way a part of the circular economy monitor for Flanders has been delivered, and the question to which extent mobility in Flanders is getting more circular can be answered to the best extent possible today. Moreover, the experiences with respect to data and data governance encountered along the way will be shared in this report as well, as the collected indicators and data also provide an illustration of the gap between the 'as is' versus the 'ideal' situation with respect to available indicators and data.

2. Materials and methods

The approach to develop indicators for the mobility system started from the preliminary elaboration published before [Alaerts et al., 2019b]. This elaboration was made in an attempt to make the published concept of systems fulfilling societal needs more tangible. Data obtained from a quick search on the websites of a number of organizations in the context of mobility had been grouped in order to create a first, rough, version of the CE monitor for the mobility system. In this exercise a number of questions were revealed with respect to the interpretation of data, the availability of more detail and the trade-offs between availability, quality and fitness for purpose of data. In a subsequent step, a cyclical process was set up in order to improve and build upon this first elaboration further. Starting from identifying the needs in terms of data for monitoring, further data sources were consulted both by investigating sources available online and by in-depth interviews with a number of policy officers directly responsible for managing and maintaining these data sources. After taking in this information and accommodating the new data, the data needs were adjusted or refined accordingly, and a next cycle of consulting data sources and policy officers could start. The final result of this process was presented on March 26, 2020, to an audience of policy officers, not only those directly consulted for data gathering but also those that might become users of CE indicators in a later stage. Feedback and further ideas received at this meeting were processed into this document.

Following data sources have been centrally considered and thoroughly investigated:

- The Federal Public Service Mobility and Transport (FOD M&T, https://mobilit.belgium.be/nl) manages data on registration of vehicles and transportation of passengers and freight. The data are obtained from the database managed by the registration office for vehicles (DIV) and from the results of a number of surveys. A number of statistics on amounts and technical details (e.g. fuel type, euro norm, age) of registered vehicles and on vehicle kilometers are published online and are available as well at the level of Flanders.
- The Flemish Department of Mobility and Public Works (Dept MOW, https://departement-mow.vlaanderen.be/nl) manages data on vehicle kilometers on Flemish roads. These data are outputs of the Promovia model, in which the results of counting devices on roads are inserted. Also, the results of a yearly survey on mobility behavior (onderzoek verplaatsingsgedrag, OVG) are available here.
- VITO (Flemish institute for technological research) manages the so-called Ecoscore indicators on the performance of vehicles in terms of climate impact, air pollution and noise (www.ecoscore.be), commissioned by the Flemish Department of Environment (Dept OMG).
- Febelauto (https://www.febelauto.be/) is the extended producer responsibility (EPR) organization for vehicles and manages data, norms and information sharing in the context of its duties. In its yearly reportings, data on amounts of recycled cars are available at the level of Flanders, and data on recycling efficiency at the level of Belgium.
- The Flemish Waste Agency (OVAM, Openbare Vlaamse Afvalstoffenmaatschappij, https://www.ovam.be/) receives data from Febelauto in terms of the regulations with respect to dangerous liquids. Besides, data on waste tyres and lubricants are reported to OVAM by the respective EPR organizations Recytyre and Valorlub.

- The Federal Planning Bureau (FPB, https://www.plan.be) is a user of data from FOD M&T, Dept MOW and Dept OMG. The data are used to feed predictions in the context of future mobility and have been made available on the FPB website.
- MIRA, the unit responsible for the State of the Environment Report (SOER) in Flanders (https://www.milieurapport.be/), is part of the Flanders Environment Agency (VMM). It publishes a series of mobility indicators based on data from FOD M&T, Department MOW and a number of other organizations. Besides, MIRA/VMM also publishes indicators on greenhouse gas emissions of vehicles (air emission inventory) and on material and carbon footprints of the Flemish consumption.

Following organisations proved to be very relevant in terms of the data that have been pursued in the context of circular economy and mobility, as reference was made to them by the interviewees on multiple instances. These organisations have not been approached themselves via interviews, but their data have been included or discussed in this report:

- The public railway company (www.nmbs.be) and the public bus company (www.delijn.be): data on passenger kilometers are available in the respective year reports;
- The Public Flemish statistics services (Statistiek Vlaanderen, www.statistiekvlaanderen.be);
- The Flemish Mobility Council (MORA, www.mobiliteitsraad.be): a selection of data is available in its year reportings;
- Carpass, an organisation that manages mileage data of vehicles in use by collecting data at every instance a vehicle undergoes maintenance, repair or another service with the aim to produce mileage certificates for second-hand cars (www.carpass.be). These data are reported to DIV;
- The technical inspection (GOCA, www.goca.be) manages mileage data of vehicles recorded at every inspection and reports these to DIV. These data are available from the moment a vehicle is in use for four years.
- Recytyre, the EPR organization involved in collection and processing of used tyres (www.recytyre.be);
- Valorlub, the EPR organization involved in collection and processing of waste lubricants (www.valorlub.be).

The data obtained from the above sources have been gathered in a datasheet, available in the Appendix. Details on the sources and own calculations have been included there. An overview of the above data sources and the relations between them has been provided in Figure 1.

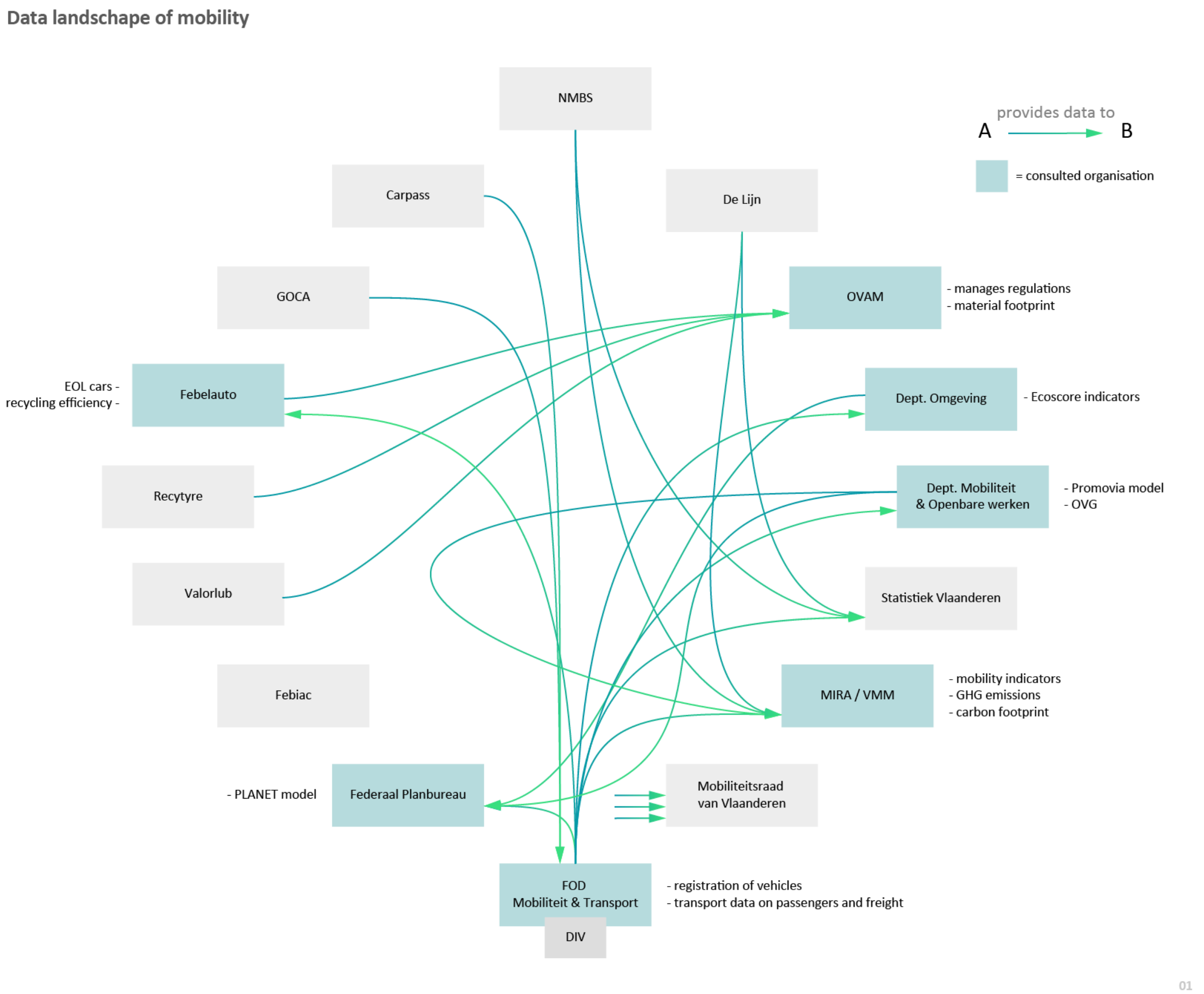

Figure 1: the data landscape of mobility in Flanders as explored within this project (organisations in blue have been consulted via interviews).

Companies or federations[1] have not been approached as the perceived bottlenecks in terms of protection of commercial position and intellectual property were considered too large in order to get to substantial progress in terms of data and indicators within the frame of this project. Also, it was realized that working with such kinds of data would require particular additional efforts in terms of data warehousing and legal aspects.

[1] Some data from Febiac have been used in this document, see below.

3. Results

In the following subsections, the results of the iterative process of determining the data needs, matching these needs with the available data and finally coming to a selection of indicators to reflect the progress towards a circular economy will be described.

3.1 Data needs

A first question in this assignment is which indicators would be ideally needed in order to measure progress to a circular economy. Already from the onset it became clear that discussing and deciding on indicators in fact comes down already to a first step in developing a policy for circular economy in mobility, which is currently not explicitly available as such. Therefore an attempt was undertaken to list a number of essential ingredients for such a policy.[2] These ingredients have been defined more tangibly along the way of interviewing policy officers and investigating the available data.

Overall, the general objective of circular economy in mobility should be to *minimize its material and carbon footprints*. The general idea of circular economy is to keep products and materials functional as long as possible at the highest possible application level, while minimizing total material-related environmental impacts. The overall result of this is that our global consumption of materials related to the mobility system should be minimized – as such circular economy connects to the context of the planetary boundaries [Alaerts et al., 2019b]. With respect to impacts, the carbon footprint is relevant given the context of climate change – evidently impacts are much broader.[3]

In a more tangible way, minimizing the material footprint can be translated into *minimizing the amounts of vehicles* needed in order to fulfill any mobility demand. The less vehicles driving around, the less will be the material demands and impacts, also with respect to fuels. This comes down to intensity and efficiency of use, i.e. maximising the amount of time vehicles are not idle and the occupancy of vehicles. In circular economy, one particular way to reduce material consumption is via the development of circular business models. Such *new models of production and consumption should effectively lead to less material consumption and impacts*, either by their intrinsic design or by taking care that rebound effects are occurring only minimally.

Focusing at the individual vehicle level, a major concern should be that *new vehicles entering the market are the most circular ones*. There is however not a simple list of criteria to judge circularity at product level: vehicles could have properties like being more long-lasting, smoothly recyclable and repairable, very light in construction and/or perfectly sized towards the intended use etc. There are a number of trade-offs, not only among the different options for a vehicle to be circular, but also with respect to meeting standards like energy consumption, safety etc. Moreover, circularity should not go at the expense of environmental impacts. In the use stage, the focus would be on light weighting, consumption of tyres, lubricants etc. With

[2] Some ingredients have been gathered from a previous study on the impact of a circular economy on reaching the climate goals [Christis and Vercalsteren, 2019b]

[3] As consumption of products is directly linked to any impact, any focus on reducing the absolute amounts of products and materials will also lead to a reduction of the impacts.

respect to the waste stage, care should be taken that *maximum value is extracted from End-of-Life vehicles* in Flanders. In the first place these vehicles should have approached the technical maximum mileage before scrapping, at least if this does not go at the expense of air quality. Car scrapping should preferably take place via recycling facilities within the own region to avoid transport and to have maximal local economic benefits from reusing car parts and recycling car materials.

3.2 Available data

In this section the data that were considered most suitable for monitoring CE in the context of mobility will be presented. This selection is exhaustive, in a sense that not all data encountered will be explicitly dealt with in a high level of detail. Rather, the focus will be on the major insights and decisions along the process of collecting and evaluating data for use in terms of monitoring CE.

3.2.1 Material and carbon footprint of mobility

In the concept of the CE monitor, the proposed systems to fulfill societal needs can be seen as disaggregations of macro economic data on final demand, for which indicators like the overall material footprint and the carbon footprint of the Flemish economy have been derived [Raes et al., 2020; Vercalsteren et al., 2017; Christis et al., 2019a]. In the figure below, the respective data describing the material and carbon footprint for the mobility system are presented.

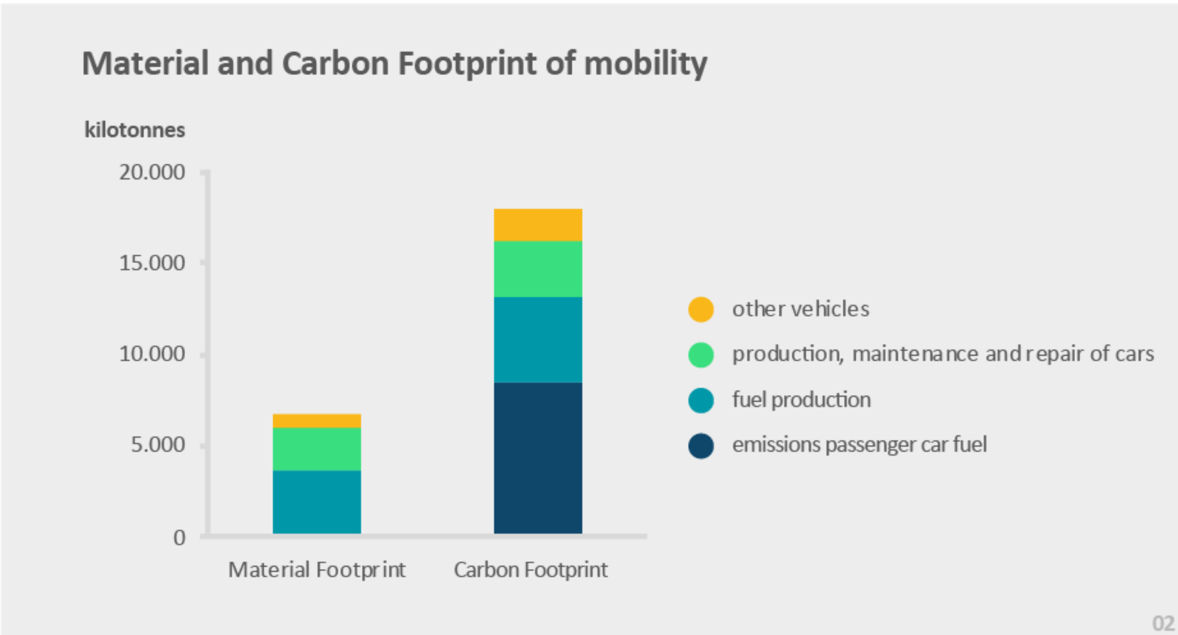

Figure 2: Material and Carbon Footprint of person transport in kilotonnes of materials and CO_2 equivalents, respectively, based on 2010 data [Vercalsteren et al., 2017; Christis et al., 2019a].

These numbers give an impression of the huge overall impacts of the fulfillment of the mobility need in terms of person transport in Flanders.[4] The numbers represent the global primary material use and greenhouse gas emissions in the upstream production networks of the goods and services that are bought in one year by Flemish household to fullfil their mobility needs. They comprise respectively 10 and 20% of the total material and carbon footprint of household

[4] Freight transport is comprised within each of the other consumption domains, e.g. food transport is part of nutrition.

consumption. A very large part of both footprints connects to production and use of fossil fuels, followed by production, maintenance and repair of cars, illustrating that the largest impact of passenger cars is to be found in the use phase. In terms of policy feedback, these data have the disadvantage that the underlying datasets are not available every year and there is a substantial delay in converting such datasets into indicators for Flanders [Alaerts et al., 2019b].[5] The most recent year for which data are available is 2010[6]. Any changes or evolutions in the economy would have to have grown sufficiently large in order to be reflected in these indicator scores. Also, any niche evolutions will not be revealed in these data.

3.2.2 Product groups fulfilling needs

Overall, in terms of fulfillment of needs, the size of mobility system can be expressed best as total distances traveled with any means of transportation. All motorised vehicles (except for some types of electrical bicycles) are registered at the Federal administration. Data on distances driven have been determined in several ways:

- by mobility surveys, asking respondents about mobility behavior. The most recent survey data for person mobility are available from the OVG survey conducted yearly by the Flemish administration. Statistics Belgium performs surveys on freight transport;
- by counting devices installed on Flemish roads. The data are managed by Dept MOW for feeding a model, Promovia, from which data on vehicle and passenger kilometers are calculated;
- based on odometer data of vehicles, which are recorded upon every maintenance operation and technical inspection and are eventually collected in the Carpass and DIV databases. FOD M&T delivers a yearly report with kilometers traveled by vehicles based on these data.

In the following paragraphs, data from these and a number of other sources will be combined in order to build a view on the amounts and types of vehicles used and on the intensity and efficiency of their use. In terms of circular economy, both intensity and efficiency are to be maximized. Increasing intensity comes down to decreasing the idle time of vehicles, while increasing efficiency comes down to maximizing the amount of passengers fitting into a vehicle.

A. Passenger cars

Amounts

The amounts of passenger cars registered in Flanders have been reported by different instances based on data requested from the DIV database (Figure 3a). They are presented in yearly reports on the website of FOD M&T, and have also been published by MORA, FPB, MIRA, Ecoscore and Statistiek Vlaanderen. As can be seen in the figure, the reported values are slightly different among these sources, deviating within an interval of ca. 1%. This is most probably due to the inclusion or exclusion of particular minor vehicle categories available in the DIV data, depending on the considerations and needs of the different entities using these data for their purposes. As this is a minor issue, and as there is no point in making a particular selection for the purpose of CE monitoring, the better option is to copy the data that have been reported closest to the data source, found in the year reports provided by FOD M&T. The current amount

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[5] The data are not yearly available and there is a substantial delay (min. 3-4 years) for the dataset becoming available: the Flemish specific data are derived from the interregional Belgian model, with data for every Belgian region (they are not derived from a model with data only at the level of Belgium.

[6] An update will appear in 2020 with data for the years 2010, 2012, 2014, 2015 and 2016.

of registered cars is above 3,5 million units, with a steady and substantial increase over the past 9 years with ca. 400.000 units. All passenger cars registered by persons of companies located within the Flemish region are included in these numbers.[7] The amount of passenger cars can also be expressed in relative terms by dividing by the amount of inhabitants (per capita) or of households in Flanders (Figure 3b). While per capita indicators are a standard way of presenting data, in the context of cars the amount of households may be more logical. The numbers are increasing with both expressions of the data.

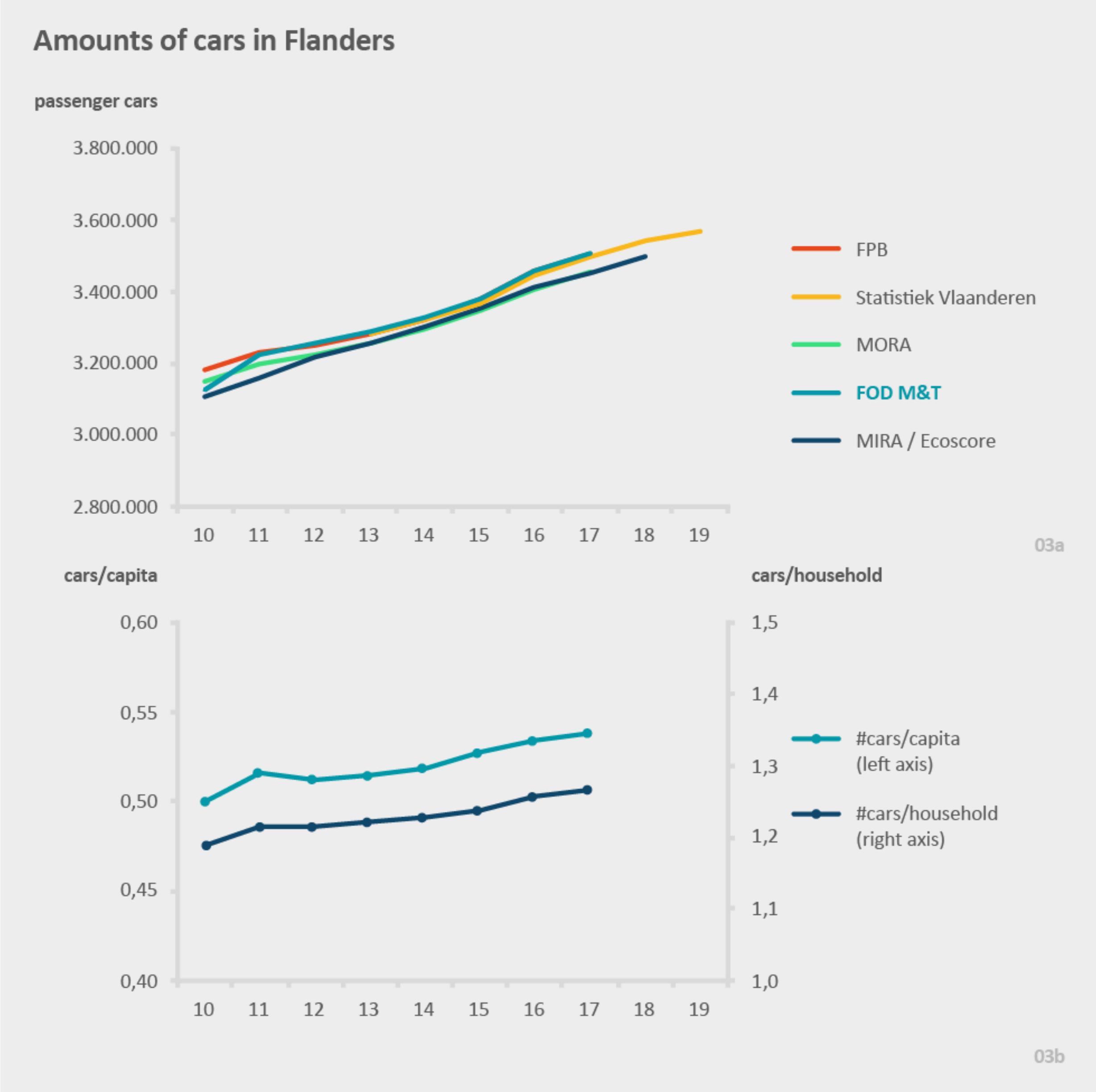

Figure 3: Amounts of cars registered in Flanders: (a) absolute amounts as reported by different data sources (see legend); (b) amounts per capita and per household based on FOD M&T data.

[7] In case of leasing companies, the location of these companies is determining inclusion – not the location of the user. Especially in the context of the region of Brussels being surrounded by the Flemish region, changes in location of such companies may affect the amount of registered cars with amounts up to several thousand units. However, the overall evolution is not expected to be substantially affected by this issue, and some compensation will take place over time as such events happen in two directions.

Car kilometers
Data on kilometers driven by Flemish passenger cars are available from two sources: odometer data and data derived from road counting devices. The data are shown in Figure 4. There is a relatively large difference of 3 to 5 billion kilometers between the two datasets. The occurrence of a difference is no surprise, as both the methods of acquiring the data and the cars considered within the datasets are very different:

- The car kilometers presented by FOD M&T are calculated based on odometer data of cars registered by Flemish residents or companies. This means that the complete distances driven with these cars is included in the data, including all trips abroad and holidays.[8] The calculations are done using an elaborated method in which for each individual car the yearly increase of the odometer is approximated by comparing the available data points within a certain time range as available from the DIV database [Kwanten, 2018];

- The data from Dept MOW are obtained as outputs from a model, Promovia, which is being fed with data from car counting devices installed along the Flemish road network. In the model these inputs are extrapolated into car kilometers for the region as a whole. All cars driving on the Flemish road network are considered in the data, including all foreign cars, and excluding trips abroad of Flemish cars.

Both datasets reveal an increasing trend (Figure 4); the downward jump in the data from Dept MOW is due to a modification in the used methodology. Comparing the two datasets comes down in fact on comparing a ‘footprint’ vs. a ‘territorial’ perspective, as FOD M&T data focus on ‘worldwide’ car use by Flemish inhabitants and Dept MOW data on car use within Flanders. For the purpose of CE monitoring from a societal needs perspective, the FOD M&T data are more suitable as they align better with the idea of fulfillment of needs. Moreover, the data quality is better due to the much more exact basis of the data and the consistency in the applied calculation methodology over the years.

[8] Also, distances driven by cars registered in Flanders but used mostly in another region are included. This situation may happen with leased cars. The reversed situation, for instance a car used by a Flemish inhabitant but leased from a Brussels-based company, is not included.

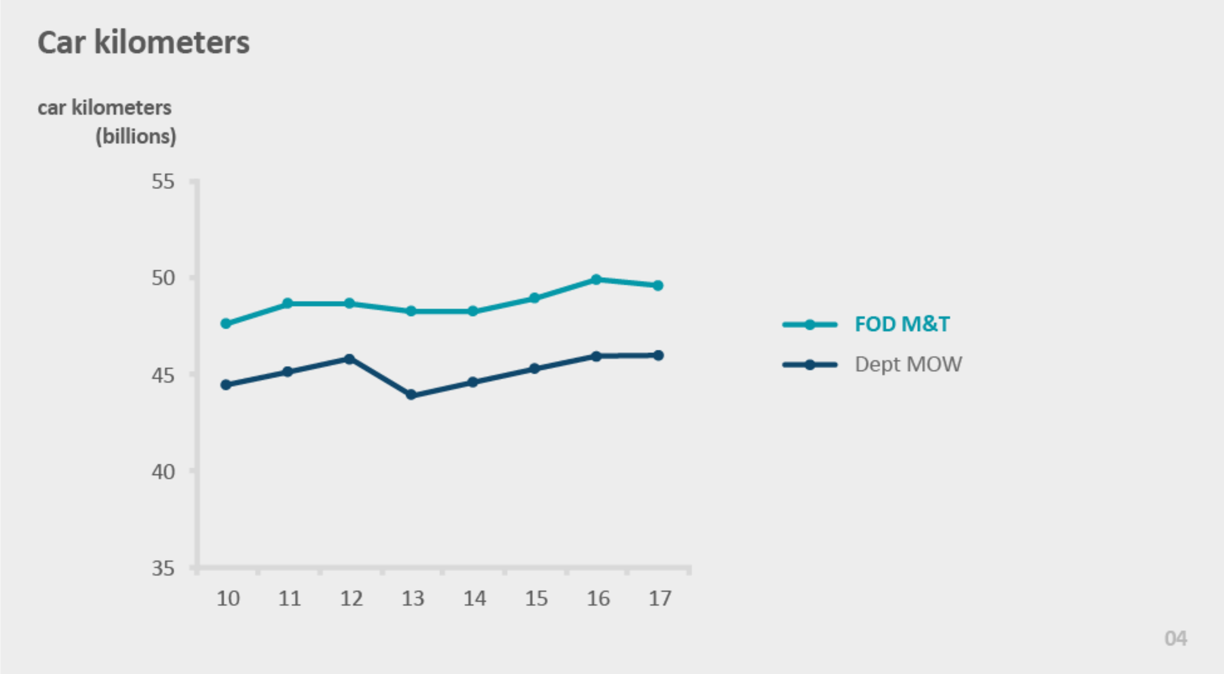

Figure 4: car kilometers (expressed as billions) as obtained from FOD M&T and Dept MOW.

Intensity of use

If in a circular economy the mobility needs are to be fulfilled with a minimization of material use, then the amount of time a car is idle is to be minimized (at least if this does not go at the expense of for instance public or light transport), and when it approaches the End-of-Life stage the reached mileage should be maximal [Material Economics, 2018]. The latter aspect will be discussed lower in the text; idle time could be inversely approximated by dividing car kilometers by the number of cars, leading to the average amount of kilometers a car drives per year (Figure 5). Again two different datasets are available, as explained in the previous section. From the above discussion on data gathering and quality, the data from FOD M&T are preferred; also, dividing car kilometers by car amounts should be done based on the same population of cars. A decreasing trend is visible, and the average amount of kilometers driven has decreased with ca. 750 kilometers between 2010 and 2017.

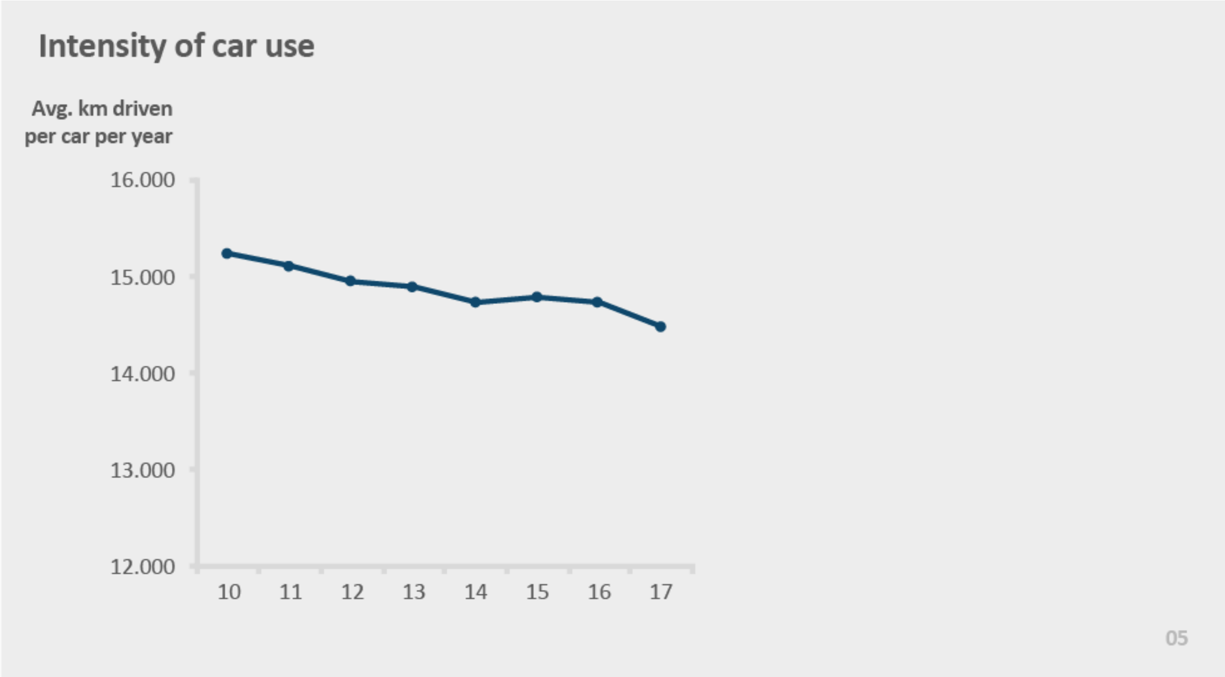

Figure 5: Average kilometers driven per car per year (based on data from FOD M&T).

A circular business model particularly relevant in the context of intensity of use is car sharing. In order to monitor the contribution of car sharing to a circular economy without adverse environmental impacts, data are to be gathered that link the current practice of car sharing for instance to the evolution of the stock of cars, the intensity of car use and/or a reduction in the use of cars at the benefit of other transport modi [Carmen et al., 2019]. Such data can be obtained either by a representative survey, by gathering data from car sharing companies[9] or by extracting data with a dedicated filter from the DIV database[10]. None of such data are available today. As car sharing is considered as an important practice in the concext of CE in mobility, it may be useful to display proxy data, awaiting the data suggested above becoming available. One possible candidate are car sharing membership data. A press release[11] from autodelen.net, the Belgian car sharing federation, reveals Flemish membership data (Figure 6). The strongly increased popularity of car sharing in recent years, even with substantial double-counting assumed to have occurred in the data, is clearly revealed here.[12]

[9] These companies are not obliged to provide data. A way forward could be to install such an obligation.
[10] Via this way only the private car sharing initiatives would be covered, using the respective company registration numbers in the filter. As a remark, the whole fleet of such companies will be included, hence not only the cars available for users.
[11] See https://www.autodelen.net/wp-content/uploads/2019/02/Autodelen_net-PERSBERICHT-Autodelen-stijgt-exponentieel-in-Belgi%C3%AB.pdf.
[12] People may apply for membership of more than one car sharing initiative in order to decrease their risk for not having a car available [Carmen et al., 2019].

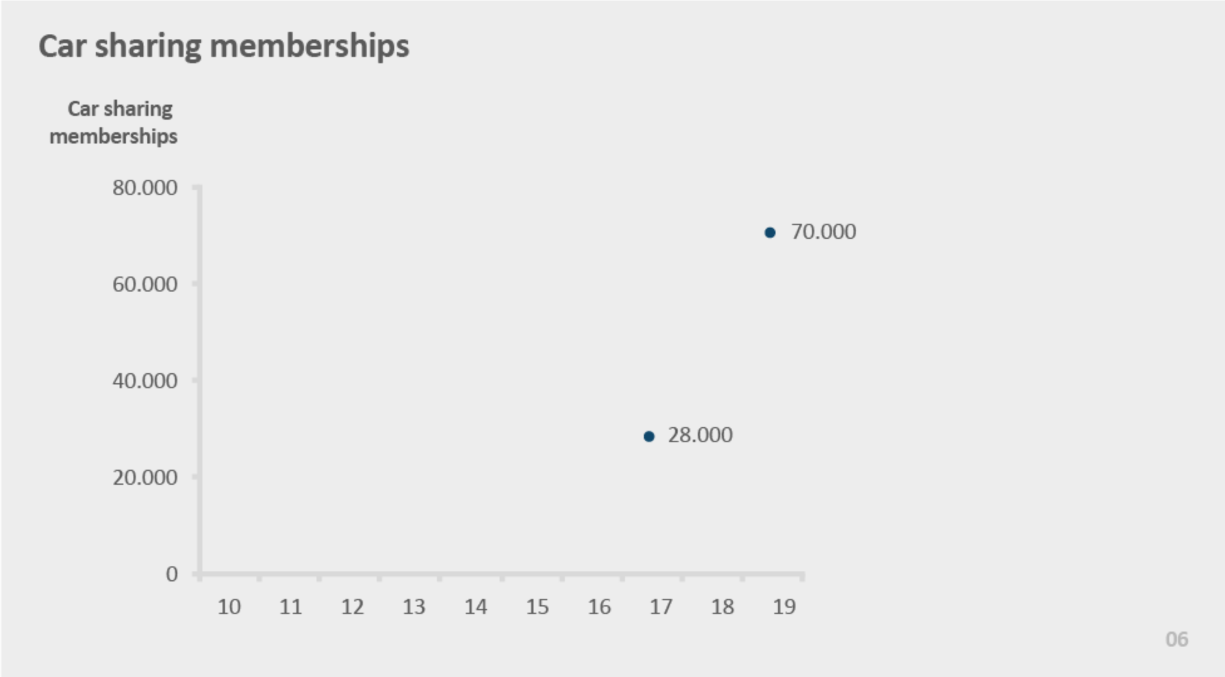

Figure 6: Amounts of car sharing memberships in Flanders (data from autodelen.net).

Efficiency of use

Efficiency comes down to maximizing the occupancy, i.e. the amount of seats taken in a car during use. A relevant circular business model in this context is car pooling. It is challenging to assess the occurrence of car pooling or, by extension, the amount of passengers traveling on average in a car. Car pooling takes place both via informal and more formal channels, and there is no central collection of data. One possible source are survey data: the amount of passengers in a car is often sampled in mobility surveys. Many of such surveys have a focus on particular situations, like commuting; only one, the OVG survey (see above), was found that delivered numbers for car occupancies for all kinds of trips made (see Figure 7). Alternatively, occupancy data can also be obtained by dividing passenger kilometers by car kilometers. Both kinds of data are available as outputs from Promovia; as the basis of this model is an input of car kilometers (obtained from counting devices), passenger kilometers will have been obtained with an assumption in the model that could however not be revealed within this project. The use of car accident statistics behind these data has been suggested in interviews, but this could not be confirmed. Eventually, it appears that there are two datasets available for car occupancy. The numbers are very different and it is not clear which dataset is the better one, although the higher numbers do no seem to approach reality as the general perception is that for the majority of car rides the only passenger is the driver (see also below).[13] Both datasets reveal a declining trend and the numbers are far below the maximal occupancy of average cars.

[13] It appeared that the occupancy data from OVG include children as passengers. It is currently not clear whether separate data on adult passengers would be available from OVG.

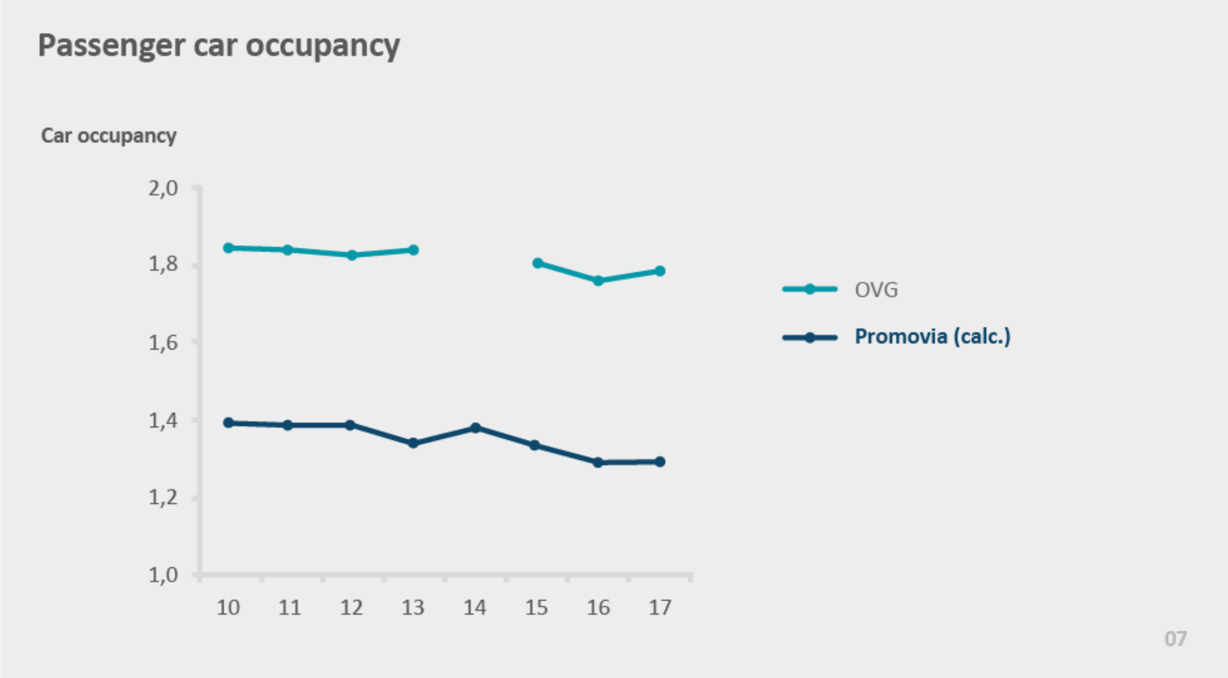

Figure 7: Car occupancy data as obtained from OVG and from a calculation using Promovia data.

Passenger kilometers

As mentioned in the previous paragraph, car occupancy is the factor linking car kilometers to passenger kilometers. The latter data have been reported directly at several instances, and can also be obtained by multiplying car kilometers with average occupancy (see Appendix). An overview of all obtained datasets is provided in Figure 8.

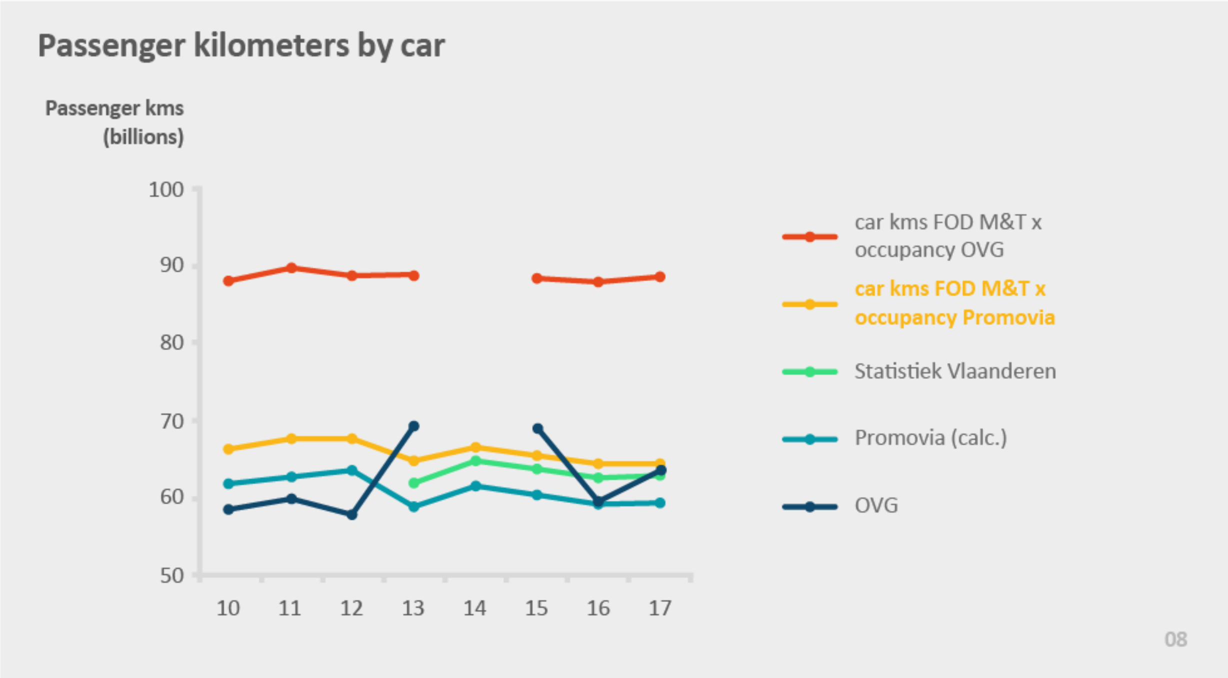

Figure 8: Passenger kilometers (expressed as billions) traveled in cars (sources: see legend; calculations: see Appendix).

Four of the datasets appear relatively closely to one another in the figure, with values around 60 – 65 billion kilometers per year. The one dataset deviating strongly has been obtained by multiplying car kilometers reported by FOD M&T (judged the better source for car kilometer data in the respective paragraph) by car occupancy data reported in OVG. The deviation seems to confirm the suggestion in previous paragraph that car occupancy data from OVG are most probably an overestimation. Using the same car kilometer data, but instead multiplying with the occupancy data obtained from Promovia, gives a dataset much better in line with other sources. The dataset from Statistiek Vlaanderen refers to FOD M&T as a source, but it is not clear how the calculation of passenger kilometers has been performed here; the very similar shape of the curve suggests that a slightly lower occupancy number may have been used. The car and passenger kilometer data from Promovia have been reported as such; as explained before, the amounts of assumptions made in the model are larger compared to the data obtained from FOD M&T. The OVG data are in the same range, but the variation over the years is much larger, most probably due to the way in which the data are obtained as such large variations cannot be taken as realistic. In conclusion, the ideal dataset does not seem to exist, and the most consistent one seems to be the one obtained by multiplying car kilometers obtained from FOD M&T with occupancy data derived from Promovia. This dataset shows a value of ca. 65 billion car kilometers driven per year, with the lower values reported in the more recent years.

B. Buses and lightrails

There are less sources reporting data from buses and lightrails, and the amount of data is more limited. The major sources of data are FOD M&T for numbers and odometer data of buses (both the ones driving as public transport (PT) vehicles and other buses), the PT company for mileage data on its bus and lightrail fleet, and from MIRA reporting passenger kilometers for PT buses and lightrails together as one number, and of other buses as another number.[14] The data are fragmented and by putting together all the available pieces of information the overview presented in Figure 9 has been obtained. The same items as in previous paragraphs on passenger cars have been displayed. Details on data sources and calculations are available in the Appendix.

The total amount of buses in Flanders is close to ten thousand units, of which about one quarter are PT vehicles. It appears that the latter are much more intensively used, with yearly distances driven ca. three times higher compared to other buses. Apparently, current PT operation stands for an intensified use of buses. Still, the value decreased from 90.000 to 80.000 between 2010 and 2018, while the number for other buses stayed more or less constant. Passenger kilometers driven in buses add up to ca. 9 billion kilometers, with a bit more than half of this amount driven in PT buses. Interpretation of passenger kilometer values should however be done with much care. There are two sources for these data: the OVG survey and data reported by MIRA from FOD M&T. The OVG data display large variations from one year to the other, as observed before for passenger kilometers in cars. For the other source, it is not clear how to assess the accuracy of passenger kilometer values. For instance for PT buses, a lot of assumptions need to be made because the real use of subscriptions is not known, neither are the distances traveled with single use tickets[15] or subscriptions. Occupancy of buses is between 20 and 30 passengers per bus on

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[14] MIRA refers to FOD M&T for person kilometers by bus and lightrail. Statistiek Vlaanderen also reports a limited set of data on passenger kilometers in all kinds of buses, referring to FOD M&T as a source. The numbers deviate slightly from those reported by MIRA.

[15] A ticket allows to travel for one hour, it is not related to any distance traveled.

average,[16] with the higher values for PT buses, and the latter are also higher in the most recent years. Given the uncertainties with respect to passenger kilometers, any further interpretation is not meaningful; the same holds for occupancies.

For lightrail vehicles, the amounts and the use are much more limited compared to buses, given that lightrails are only in operation in two cities and along the coast. Passenger kilometer values have been derived from OVG, the only source listing this number separately. Data on vehicles

[16] Occupancies have been obtained from dividing passenger kilometers by vehicle kilometers in the figure. It is not possible to calculate meaningful filling percentages as sizes of buses are very different.

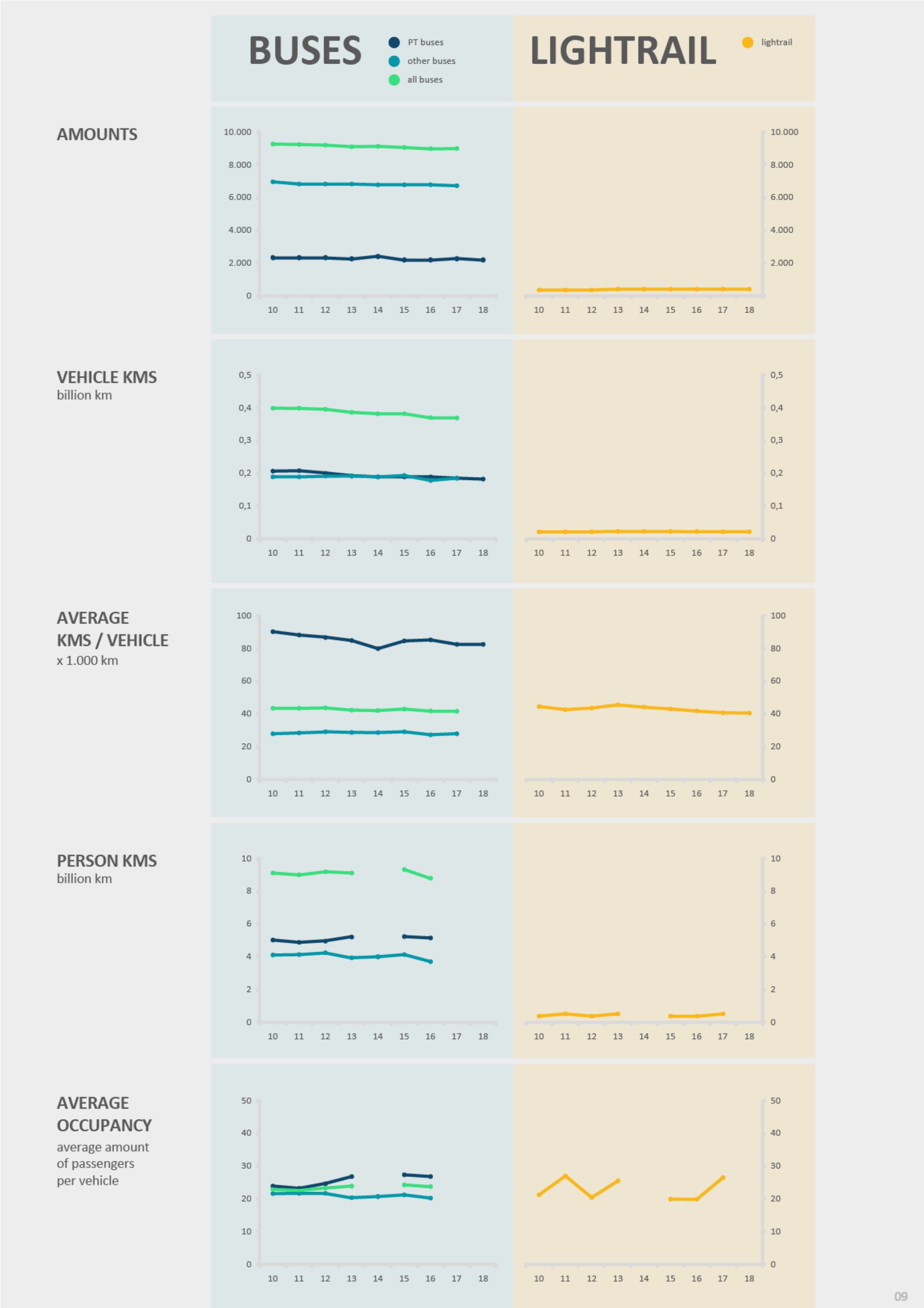


Figure 9: data on buses and lightrails.

and vehicle kilometers have been obtained from the website of the PT company. Kilometers per vehicle and occupancies have been calculated based on these data (see Appendix). There is quite some variation over the years, probably inherent to the collection method of the data. Interestingly, while occupancy appears to be in the same range of that of buses, the average kilometers driven per vehicle are much less compared to PT buses.

C. Trains

For trains, the only data found at Flemish level are passenger kilometers, reported by OVG and by MIRA and Statistiek Vlaanderen which report the same values as obtained from year reports of the railway company (Figure 10). The latter values are clearly the more consistent ones. The data display a fluctuating trend without a clear direction. They are not available as such anymore for Flanders since 2010 from the railway company, but they are derived from Belgian numbers, of which the share of Flanders is calculated using a trendline from before 2010. In the Belgian numbers, modifications took place in 2010 and 2015 when particular high-speed trains were no longer included in the data. The details of the method to determine person kilometers are not known; most probably there will be similar limitations compared to PT buses, but to a smaller extent as subscriptions and a large part of individual tickets can be based on effective distances traveled. Data on train vehicles were not available: amounts are not reported anymore since 2010; data on vehicle kilometers were not retrieved. Hence no indications of efficiency or intensity of use can be given.

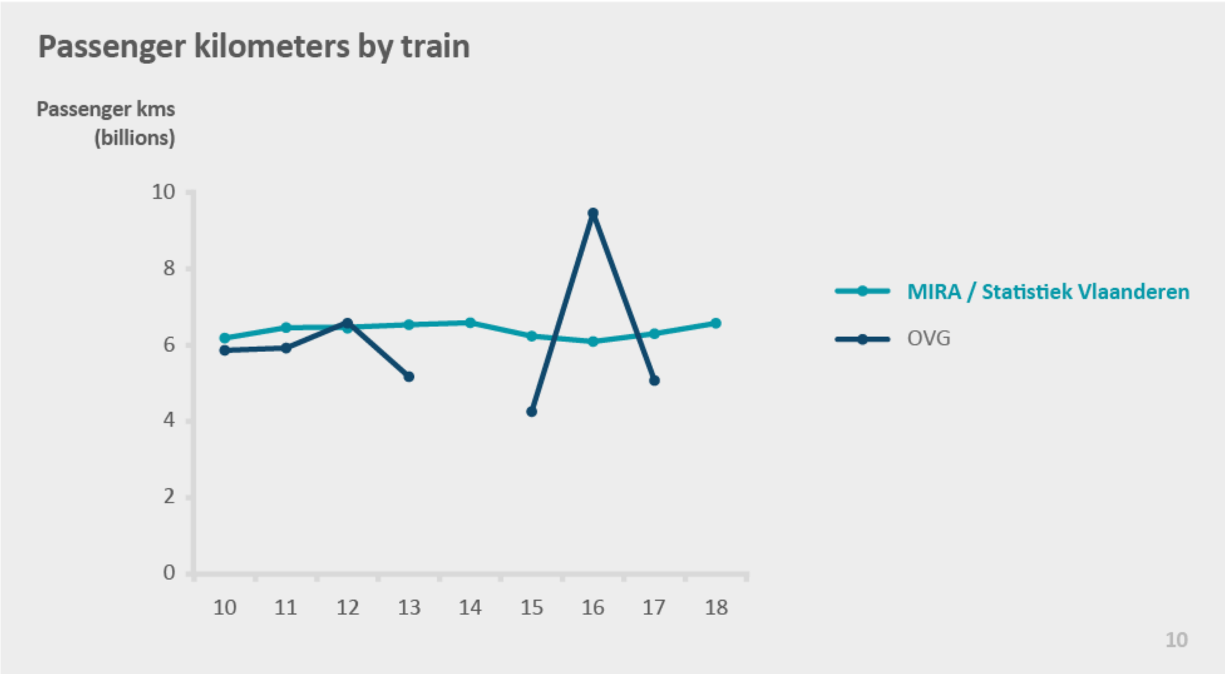


Figure 10: Passenger kilometers traveled in trains (expressed in billions).

D. Other transport modes

For motorcycles and (electrical) bicycles no further effort was done to obtain detailed data except for the passenger kilometers as available from OVG. The amount of motorcycles is very small compared to other vehicles. For bicycles, it is very clear that in terms of material consumption they are much more efficient per kilometer traveled. This becomes immediately clear when making the ratio between the mass of the driver and the mass of the vehicle, and gathering more detailed data will not change the conclusion.[17] As mentioned above, OVG data display quite some variations throughout the years, but they give an impression of the ranges of the use of these lighter modes of transport. Overall, passenger kilometers by bicycle and electrical bicycle are only a bit below the amount of kilometers driven in PT buses (see Figure 11). Motorcycle kilometers are in the range of lightrail kilometers. Kilometers made on foot are around one billion kilometers per year.

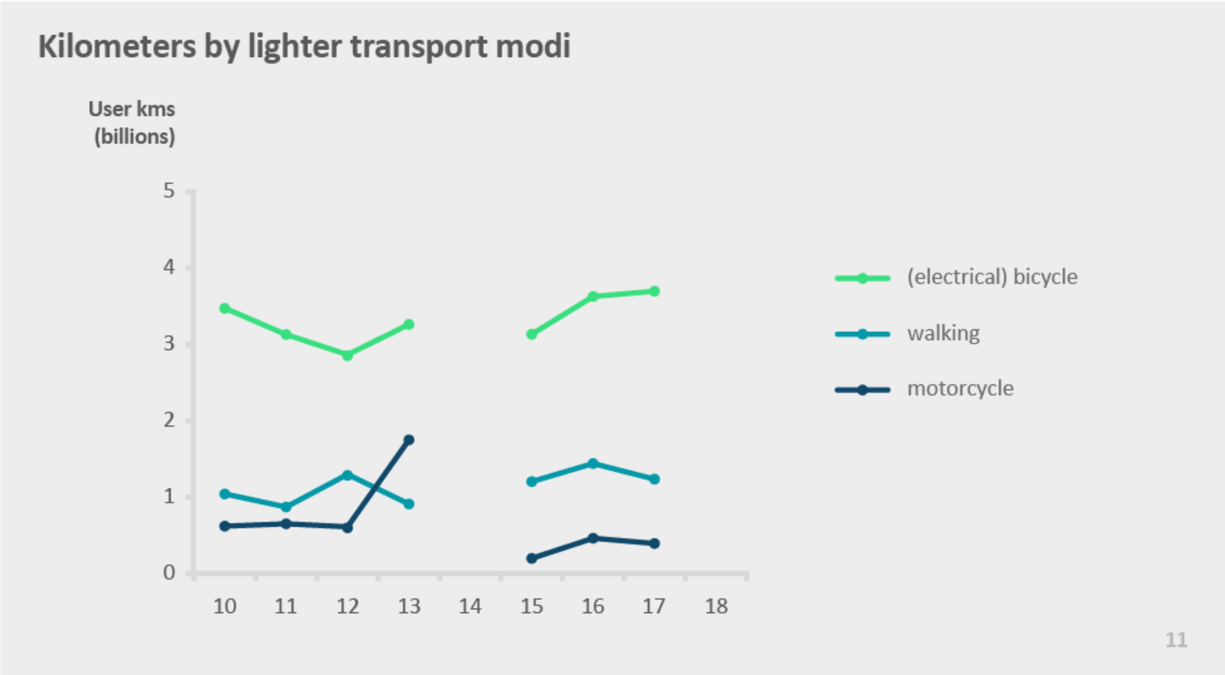


Figure 11: Kilometers made by lighter transport modi (source: OVG).

E. Amounts of person kilometers traveled and modal split

As an overview and summary, in this paragraph the total amount of passenger kilometers traveled by any means is presented, coming down to a representation of the size of the mobility system. While these data are available from OVG (Figure 12a), given the large fluctuations in these data for a number of vehicles[18], the passenger kilometer data were replaced by data from other sources that appeared the most reliable based on the analyses in previous paragraphs (Figure 12b and c). Data were not available for all categories for 2014 and 2017; for these years no data are shown. In Figure 12b, the total amount of passenger kilometers adds up to ca. 85 billion kilometers. From Figure 12c, it is apparent that car transport takes the largest part (about three quarters), followed at a large distance by four modes very similar in amounts of kilometers driven: transport per PT bus, other bus and train, and the combination of lighter transport modes. All values are relatively constant over the years.

As a note, two other categories of vehicles have not been further considered in this project: airplanes and boats. For airplanes, accommodating a fleet or airplanes in a CE monitor

[17] This needs to be nuanced in the context of the recent popularity of e-bikes and speed pedelecs (also for daily commuting), which are more heavy and contain engines. These modes of transport need to be treated more in detail for a next version of the monitor.

[18] This may have to do with the relatively small sample size. A peculiar fact in the OVG data is the very large variation in the category 'other means of transport'.

dedicated to Flanders is not meaningful given the international context of air travel. Boats have been omitted as passenger transport by boat is negligible in Flanders.

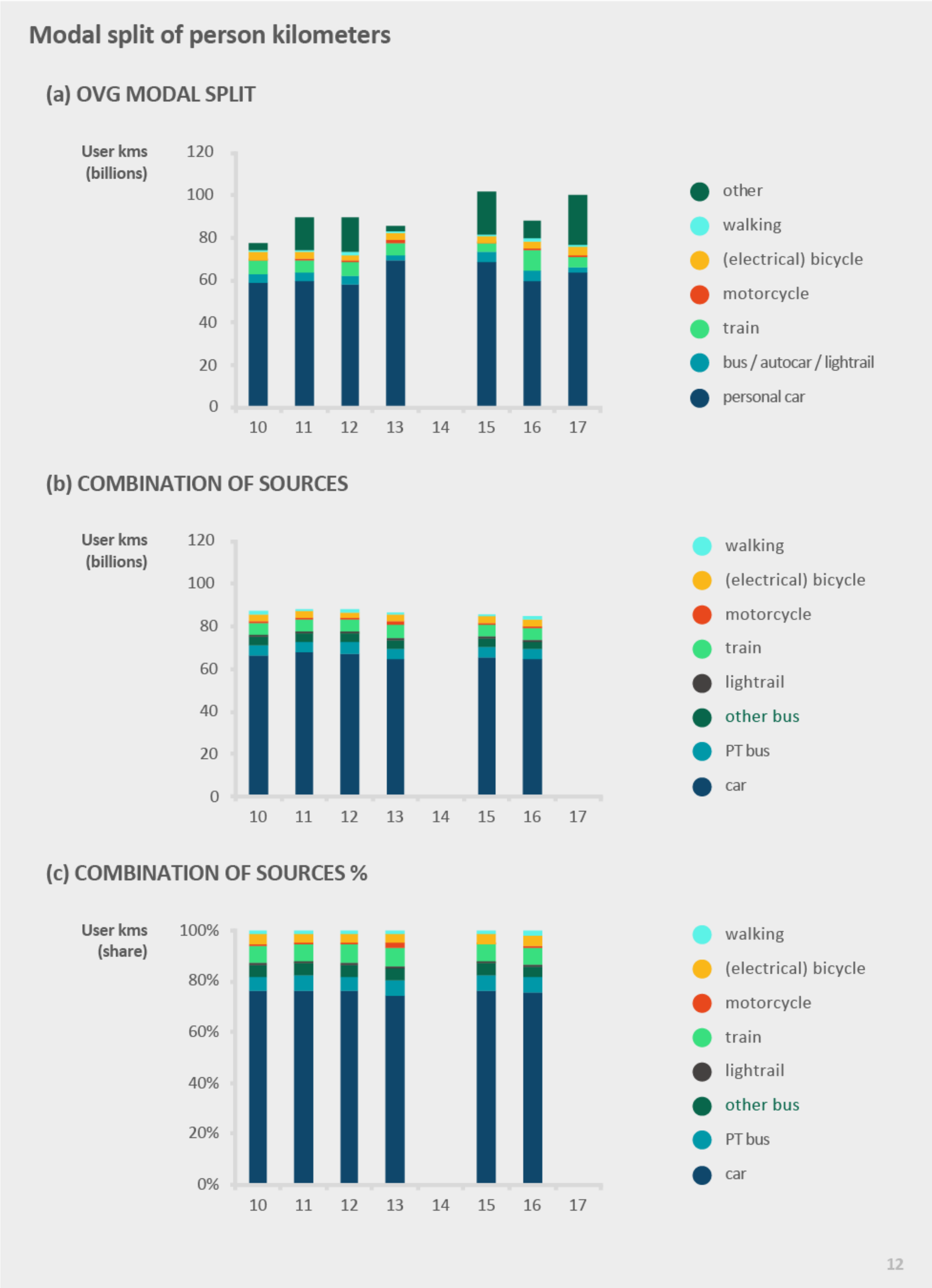


Figure 12: (a) OVG modal split data; (b) person kilometer data composed from different sources (see text); (c) same, displayed as percentages (all data in billions of kilometers; no OVG data for 2014, no PT bus data yet for 2017).

3.2.3 Freight transport

Three modes of transport will be considered here: trucks, trains and boats. Airplanes are omitted for similar reasons as explained above. MIRA provides tonkilometer data (i.e. the freight equivalent of person kilometer data) for road, train and ship transport. Road transport data comprise data on all trucks driving on Flemish roads (including foreign ones), irrespective of whether departure location and/or destination are located in Flanders. The values are obtained by combining data from Promovia with survey data collected by Statistics Belgium. Vehicles with loading capacity below 1 tonne (e.g. vans) are not included in the data. Data on freight transport by train are obtained from Statistics Flanders, which refers to the railway company and own calculations. Data on freight transport by ship are obtained from the calculations performed in-house at VMM in order to compose the inventory of emissions to air.[19] As can be seen in Figure 13, ca. 80% of freight transport takes place per truck, and there seems to be an increase in truck transport in the more recent years, however this may be rather due to methodological issues.[20]

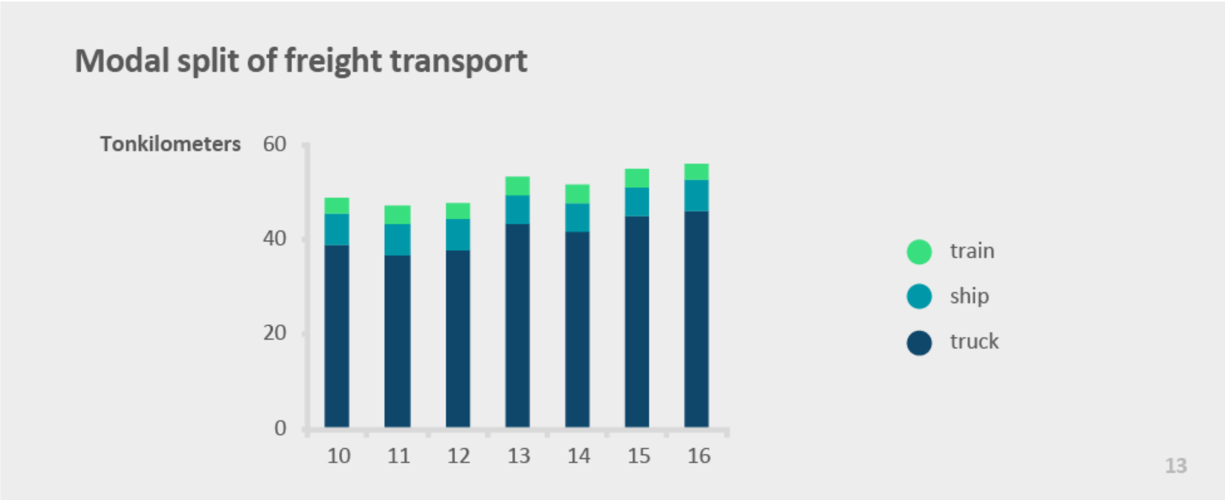


Figure 13: Modal split of freight transport by trucks, trains and boats expressed in billions of tonkilometers.

In the following paragraphs, more data on trucks are provided. Data on trains and ships are very limited. For trains, there are no data on vehicles after 2009 and no data at all on vehicle kilometers. For ships, FPB provides data on different kinds of vessels up to the year 2010. These are not further discussed in this report as it is not clear how to make selections from these data for the purpose of this work.

For trucks the same kind of data representations as in the paragraphs on passenger transport can be made. For the amounts of trucks and vehicle kilometers, three categories are reported by FOD M&T: vans, trucks consisting of a single element and lorry cabins[21] (Figure 14). It is clear that the amount of trucks and lorry cabins has stayed relatively constant over the years, while

[19] Statistiek Vlaanderen provides data on freight transport by ship as well, but lower values are obtained. The data delivered by VMM are directly obtained from the waterway management organisation and an estimation for waterways without data is added in the data as well.
[20] Methodology changes took place in 2013 (Promovia) and 2015 (Statistics Belgium), hence comparison of data before and after these dates is difficult.
[21] Data on lorry trailers were not retrieved.

there is a very strong increase in vans of ca. 25% over the time interval considered, taking the complete increase of all freight vehicles on their account.

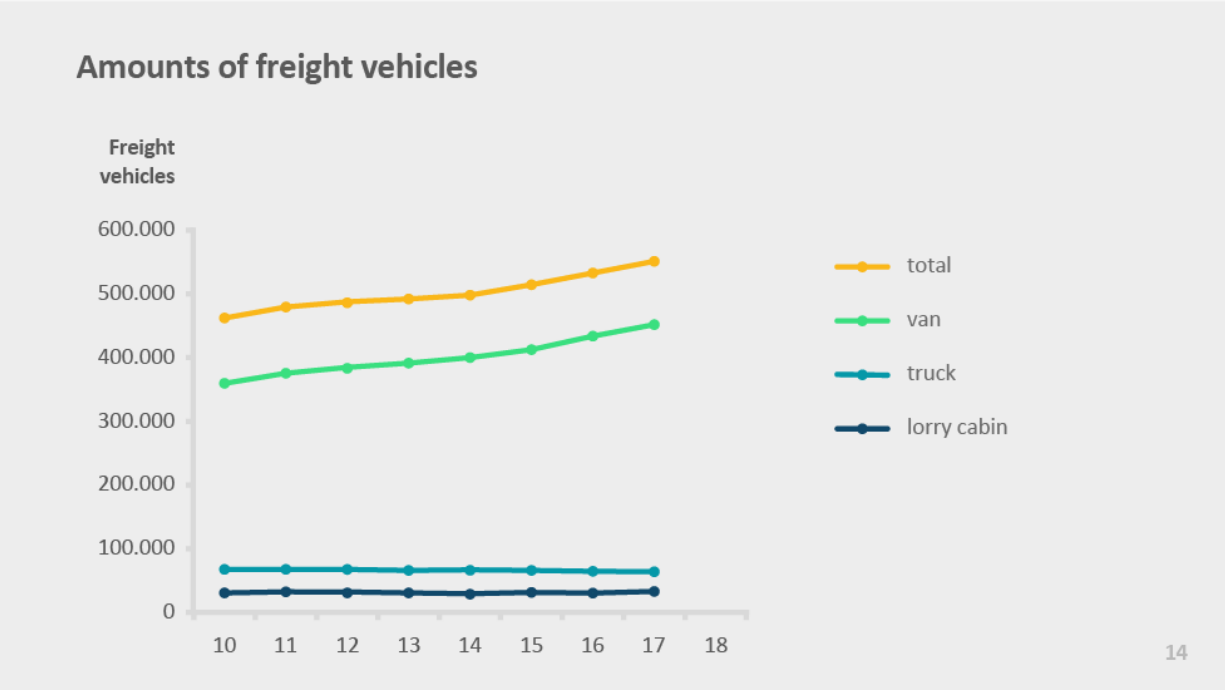


Figure 14: amounts of freight vehicles.

In Figure 15 the vehicle kilometers of these vehicles are shown, as obtained from the same source. As explained before, these numbers are based on odometer values and hence refer to vehicles registered in Flanders and the total distance driven, also abroad. The amount of vehicle kilometers seems to have slightly decreased for trucks and lorry cabins, while there is a substantial increase for vans, although not of the same size as in previous figure (ca. 15% over the interval considered).

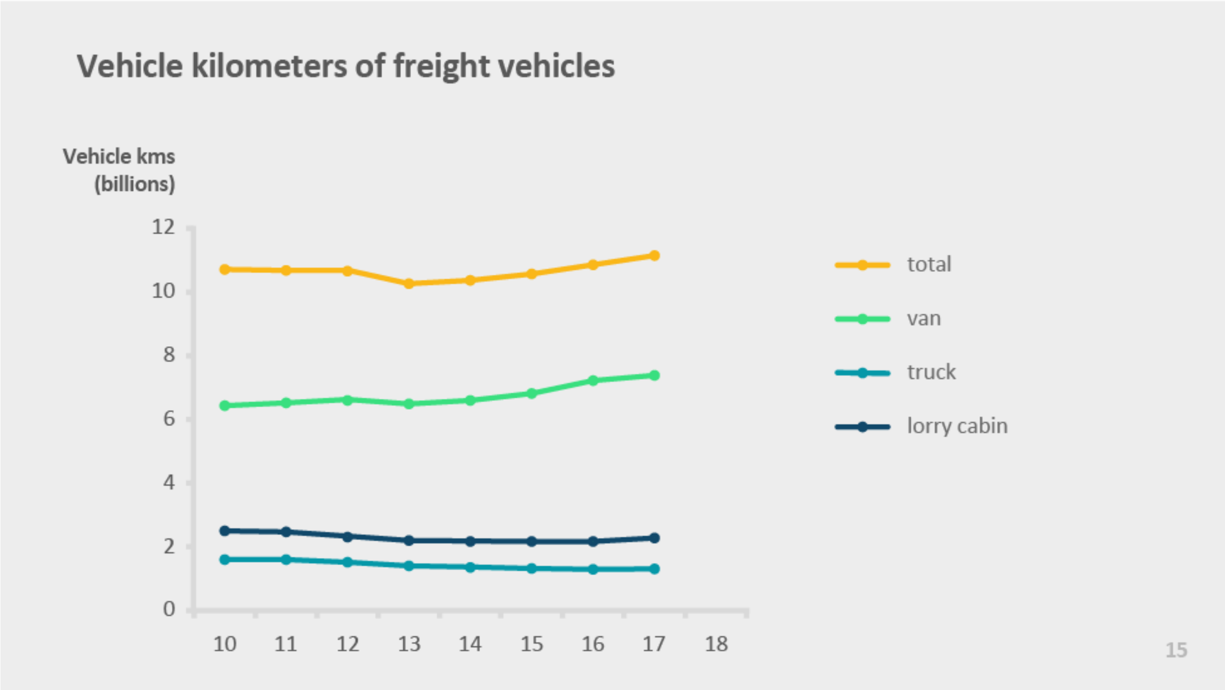


Figure 15: Vehicle kilometers of freight vehicles expressed as billions.

By dividing the values in the figures above, average kilometers driven per vehicle per year are obtained (Figure 16). The intensity of use of all vehicles has steadily decreased over the considered time interval, with the same relative amount of ca. 10% for all vehicle categories over the considered time range.

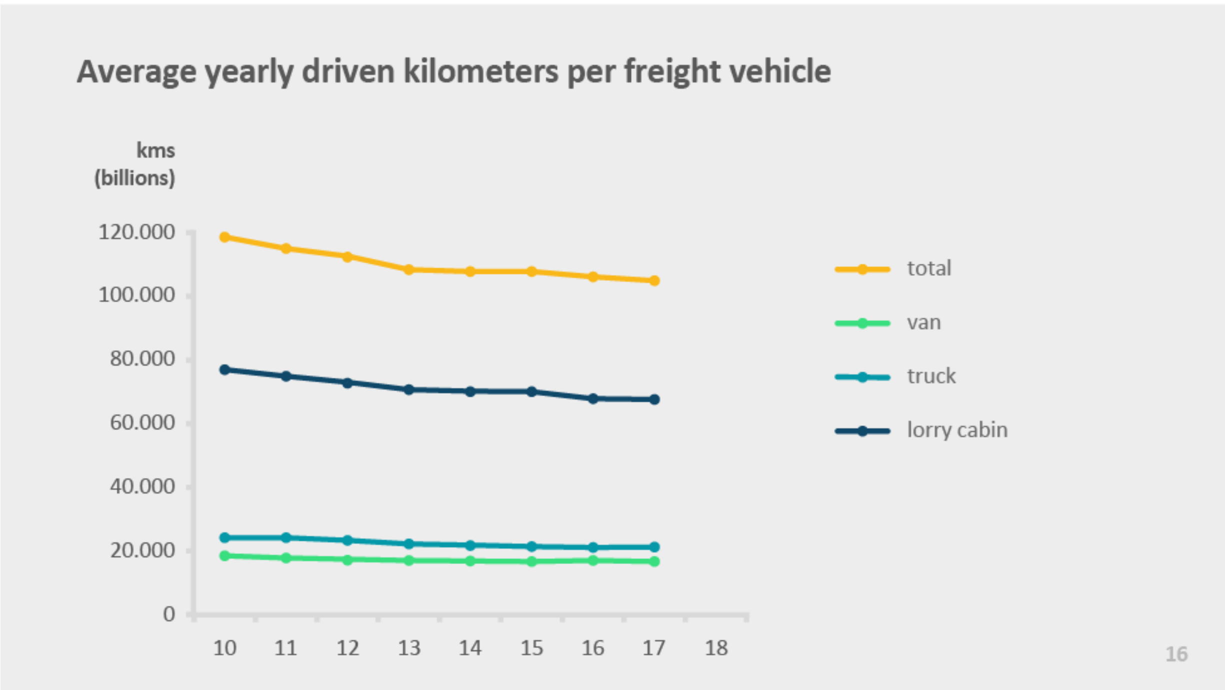


Figure 16: average amount of kilometers driven yearly per vehicle.

For the efficiency of transport, an indicator could be the amount of loading space that is effectively occupied in trucks and lorries. Such a number could be approached by dividing tonkilometers by vehicle kilometers, but this is not possible from the data that have been collected here[22]. First of all, the tonkilometer data have been based on the Flemish region while the vehicle kilometers are based on Flemish vehicles[23]. Also, more detailed data on the size (and hence the maximal load) of the vehicles would be required as a reference.[24]

3.2.4 Life cycle of vehicles

From the above, it is clear that in terms of materials and impacts, the largest part is taken by passenger cars. In this section more details on cars are given, based on the data that could be acccessed. There is a large variation in cars on the Flemish market, given the relatively long lifetime of cars – the average age is close to 9 years, as reported by Febiac. In order to see the evolution in terms of CE more clearly, three focal elements will be chosen in this section: new cars entering the market, materials consumed during the use of cars (the phase taking the largest fraction of material consumption and impacts), and the End-of-Life stage of cars.

A. New cars on the market

Ideally, circular economy indicators at the level of individual cars would include details on the material composition of cars, with indications of e.g. recycled content, recyclability etc. Making this full assessment was not feasible within the scope of this project, given perceived bottlenecks at the level of commercial and intellectual data protection. In order to make progress, intensive collaborations with car manufacturing companies would be required in order to convince them to share data for the purpose of monitoring and steering the circular economy, and this in such a way that this would at the same time be beneficial for these companies while protecting their commercial and intellectual stakes. As an alternative, three datasets were retrieved that already give some indication of the material and environmental impacts of new cars on the market, both available from Ecoscore managed by VITO (Figure 17). Masses of cars seem to have slightly increased over the years.[25] For the Ecoscore values, the numbers are composed of three parts: half of the score accounts for well-to-wheel greenhouse gas emissions, 40% for air quality and 10% for noise. The overall score is hence a weighted average for environmental performance; it steadily increased over the years. As climate impact is the most important part of this score, it has been displayed as well separately in Figure 17, and shows a decreasing trend, until very recently, probably due to the shift away from diesel cars as evidenced for instance in the respective Ecoscore indicators available online.

[22] A number on average filling rate has been published by De Standaard in 2018 [http://www.standaard.be/cnt/dmf20190212_04172259] but the source of the data was not revealed.

[23] Most probably territory-based kilometers are available from Promovia – these were not retrieved in this work – but then the obtained number would comprise all transportation vehicles, not only the Flemish ones.

[24] A source to consider for further work is Flanders innovation cluster for logistics (VIL, https://www.vil.be).

[25] A much larger increase of the average mass of cars has taken place in an earlier period [De Caevel and Huppertz, 2017]. Towards the future the expectation is that electrical vehicles will be more heavy.

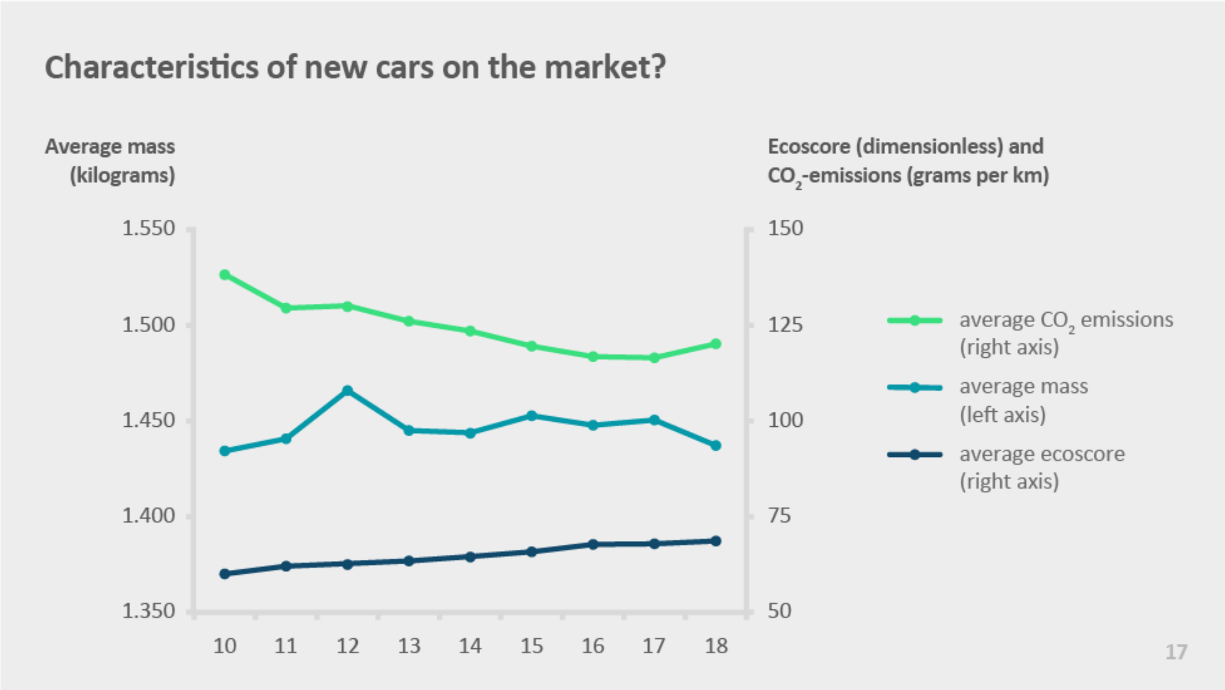


Figure 17: Average masses (left axis), Ecoscore values and CO_2 emissions (both on the right axis) of new cars on the market.

B. Use of cars

Fuels

Fuels comprise the largest amounts of materials consumed during the lifecycle of vehicles. This not only comprises the fuels themselves, but also the materials needed for production and transport of fuels. In figure 18 fuel use of road transport in Flanders has been shown, based on data of MIRA (that refers to the energy balance of Flanders from VITO as a source). These data can be taken as a proxy for the evolution of the complete material use connected to fuels (only fossil fuels are shown; other sources are currently negligible). In these data passenger and freight transport are both comprised. Diesel takes by far the largest amount, connected to the fact that almost all truck transport and the majority of car transport make use of this fuel. Petrol[26] comes next, biofuels[27] are much smaller and CNG and LPG negligible. For diesel and petrol the same trend is visible: first a decrease, next an increase from 2013 on. This is most strongly visible in diesel, most probably connected to the evolution of the economy being reflected in truck transport. For petrol, which is almost only used in passenger cars, the trend is similar to the one seen in car kilometers driven (Figure 4, FOD M&T data). In order to give a better impression of the size of this consumption alone, the values for the year 2016 were converted into fuel volumes as ca. 4,7 billion liters of diesel and 1,0 billion liters of petrol.[28]

[26] This is the same as gasoline (US) or benzine (Flanders).
[27] Biofuels take into account the obligation by the EU to mix these fuels with diesel and petrol.
[28] For diesel an energy density of 38,6 MJ/L was taken, for petrol 34,2 MJ/L (source: Wikipedia).

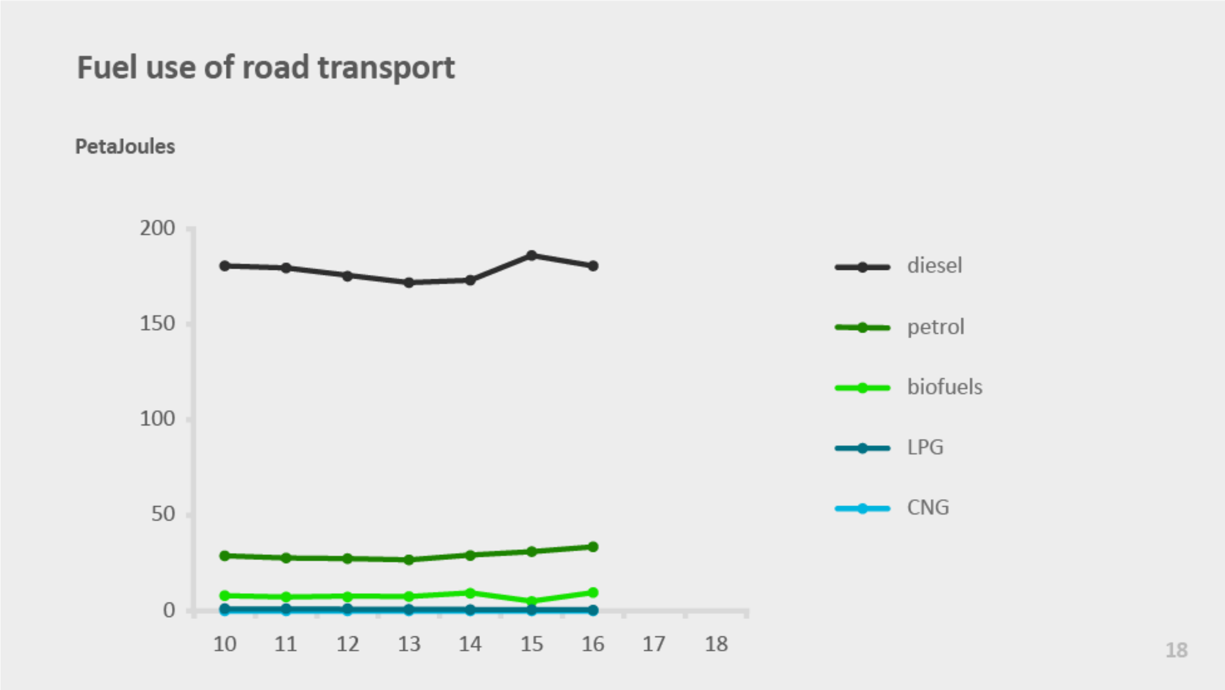


Figure 18: Fuel use of road transport expressed in PetaJoules.

As a measure for the impacts of fuels, greenhouse gas emissions in Flanders by fuel use are shown in Figure 19.[29] Impacts are of course much larger taking into account impacts outside Flanders as well as other impacts categories like fine particles or NO_x.[30]

[29] These numbers do not take into account foreigners filling up their tank in Flanders and Flemish inhabitants fuelling up abroad (for international greenhouse gas emissions the amounts of fuels sold in Flanders need to be included). Logically, the curve for person transport is identical in shape to the Promovia data shown in Figure 4, which are directly at the basis of the calculation of these emission data.

[30] For instance MIRA provides indicators on emissions of the air polluents NO_x, NMVOC, $PM_{2,5}$ and SO_2. See also the respective Ecoscore indicators. Also the impacts of dust from tyre wear are relevant.

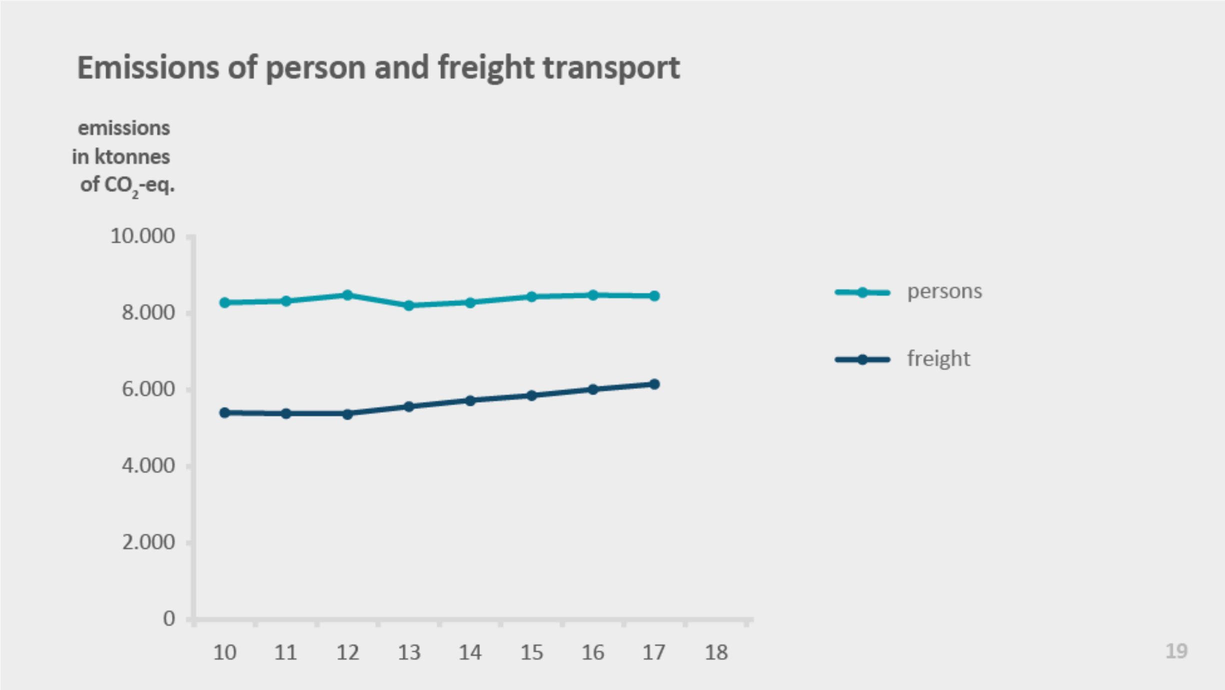


Figure 19: Emissions in ktonnes of CO_2-eq. of person and freight transport.

Tyres

Tyres are major consumables throughout the life of a vehicle. In Belgium, Recytyre is the EPR organization managing collection and processing of used tyres and providing data on the performances of these operations.[31] Collection of old tyres is organized in combination with the sale of new tyres, and the collection rate approaches 100% already for several years (Figure 20). Collection rates are only available at the level of Belgium; these numbers were taken over here as the situation in Flanders is not expected to deviate substantially from the one in other regions. In Flanders around 55.000 tons of tyres are collected of which about half originate from cars [Dierick, 2018]. With respect to the processing of these tyres, a distinction is made among the following options:

- reuse: if quality allows, this is the most rewarding option both in terms of economic value and of making the best use of materials;
- reprofiling: this is only applied on truck tyres;[32]
- recycling: tyres are processed into granulate for use in applications like small wheels, tiles, carpets, and a very small amount as reducing agents in steel manufacturing. A major application is the application in sport fields in order to improve technical characterists; this practice has been criticized for possible health issues.[33] While at first sight recycling is better than incineration, all of these applications come down to a considerable degree of downcycling, and an analysis on what has been replaced in reality and broader impacts would need to be added in order to judge the extent to which these practices should be considered part of the CE;

[31] This only concerns tyres in the replacement market. Data on tyres of End-of-Life vehicles are comprised within the recycling efficiency data of Febelauto (see below).

[32] Smarter circular economy solutions for tyres in general have been developed, see e.g. 'tyres-as-a-service' by Michelin (see https://digital.hbs.edu/platform-rctom/submission/michelin-tires-as-a-service/).

[33] See https://www.theguardian.com/us-news/2019/jun/25/lawmakers-concerned-chemicals-rubber-playgrounds-push-safety-rules

- energetic valorization: the majority takes place in cement industry, and a very small part in pyrolysis installations for energy production.

In Figure 20, downstream processing of collected tyres is shown. The majority of tyres is recycled into rubber granulate. Incineration has steadily decreased of the years up to a current value of only a few percents. The target at the Flemish level of 55% for all categories except for energetic valorization is largely met. The 'higher' CE strategies, reuse and reprofiling, seem to have each been applied in the past considerably more and seem to have decreased more recently at the expense of recycling. The reasons for this are not clear.

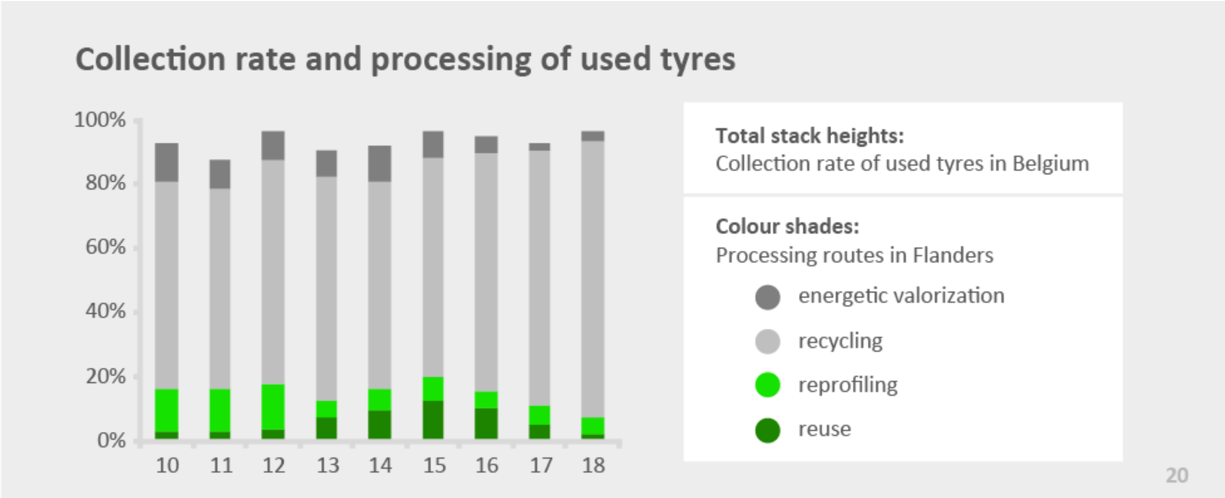


Figure 20: Collection rate of tyres in Belgium (total height of the bars), proportionally subdivided into the different downstream processing routes as applied in Flanders (shades).

Lubricants

With respect to lubricants, data on collection and recycling are reported by Valorlub as the responsible EPR organization. However, the data do not allow disaggregation for Flanders into lubricants for vehicle engines.[34]

C. The End-of-Life stage

With respect to car scrapping and recycling, a number of data for Flanders are available from the year reports of Febelauto, the EPR organization at the Belgian level. First, Febelauto reports on the End-of-Life stage of cars taking place via the official car demolition centres located in Flanders (i.e. the ones that comply with regulations with respect to safe depollution of lubricants, brake and airco liquids) (Figure 21). The numbers comprise both cars and vans, and refer to vehicles received, hence not to the location of the last owner or user neither to any evidence that a car has been effectively been in use in Flanders. This is relevant as some larger demolition facilities are located close to the borders of Flanders; of course the reverse situation also takes place, i.e. cars from Flanders ending up in demolition centres in other regions. As can be seen, over the period covered, the number strongly decreased from 2010, while in recent years a substantial increase can be noticed. While in terms of circular economy, the idea could

[34] Data on recycling or incineration were not retrieved within this project.

be that this number should be 'as high as possible', it is not straightforward to interpret the data in Figure 21 as the numbers rather reflect broader tendencies in the economy. For instance the number of cars sent for official demolition relates to the evolution of the economy, of how much incentives are in place to turn in cars for demolition, and how interesting it is to abandon a car outside the official circuit. In order to interpret this number, the total amount of EoL cars would have to be known. One difficulty in obtaining the total amount of EoL cars is that it is not possible to know whether a car that changes from owner will be used for another lifecycle or demolished elsewhere. For Belgium the amount of cars with unknown whereabouts has been estimated at ca. 50.000 units.[35] In conclusion, reporting on the amount of cars recycled within Flanders would only be meaningful in the context of CE if a denominator indicating the total amount of cars ready for demolition would be available.

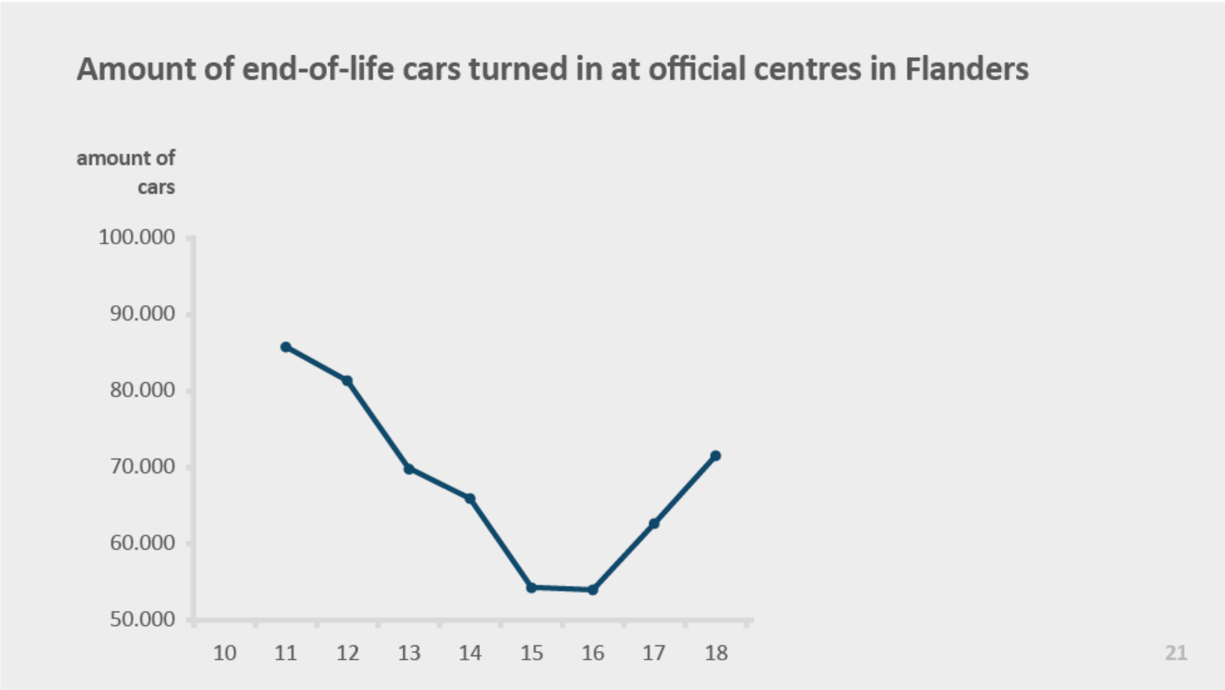


Figure 21: Amount of cars turned in at official centres in Flanders.

When a car is to be demolished, ideally it has been used 'as long as possible' under the condition that there is no negative trade-off with use phase emissions. The part 'as long as possible' could be measured via the odometer data at the moment of demolition. This number could be approximated in principle from combining existing datasets: while the odometer data are not extracted at End-of-Life for cars delivered at official centres, the Vehicle Identification Numbers are registered, and these could be crossed with the last available mileages in the databases of DIV or directly at GOCA or Carpass. An alternative could be to take a representative sample at the demolition centres themselves (but in that case it is more difficult to allocate cars to any ownership in Flanders) or to direct a request to DIV (which is more challenging, as the label

[35] The sale of a passenger vehicle by a citizen is not strictly bound to regulations; there is no contract or formality required. The license plate is to be sent in for deletion in order to end paying taxes on the car. The estimation of 50.000 cars with unknown whereabouts is a result of the Entrave project, see www.febelauto.be. This concerns vehicles from which the license plate has been turned in without any further information on the fate of the vehicle. Options other than demolition could be for instance storing in a garage, becoming a collector's item, or export.

‘demolished car’ has to be described in some way in order to apply a filter on the data[36]). As a proxy, the average age of demolished cars is available via the annual reporting of Febelauto (Figure 22). This number has been increasing from 14 to more than 16 years over the considered time interval. This increase is larger than the decrease in yearly kilometers driven per year (Figure 5), suggesting that EoL cars might perhaps have reached higher mileages in recent years.

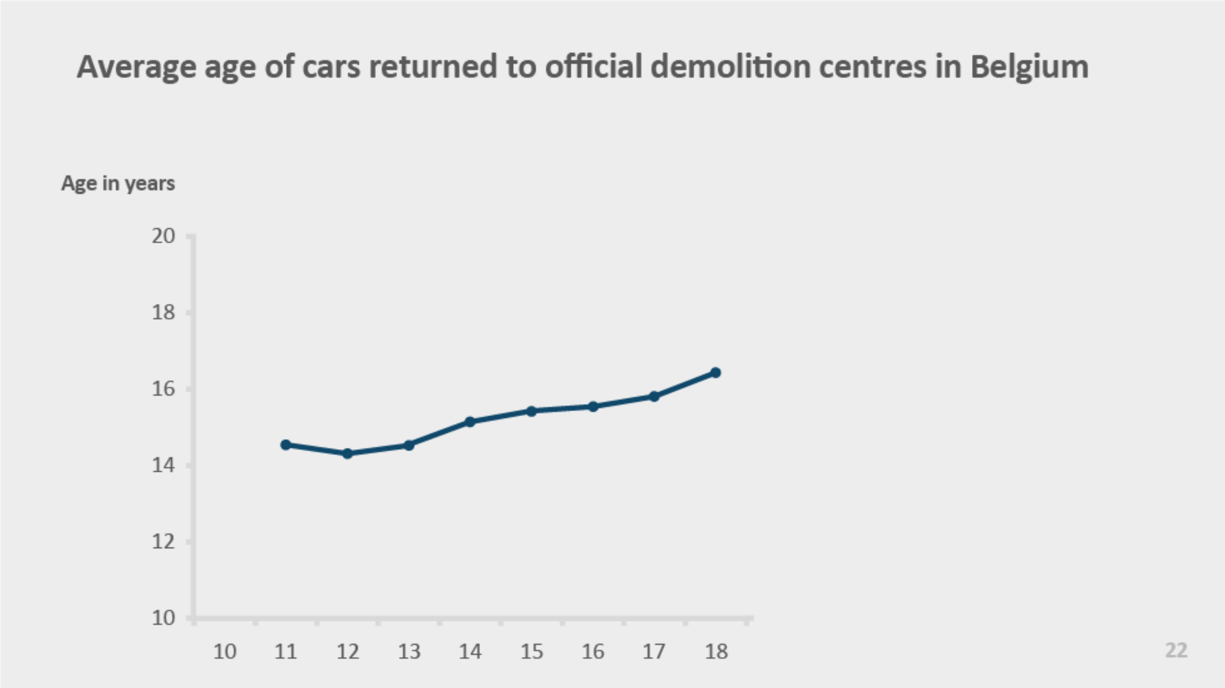


Figure 22: Average age of cars returned to official demolition centres in Belgium.

Next, with respect to the trade-off for exhaust emissions, it would be valuable to measure to which extent the more polluting vehicles are removed from the market. This will be further investigated within the policy research center. A basis to start with the development of an indicator could be to cross the list of VINs of EoL cars with the Ecoscore database which provides more detail on exhaust characteristics.

Febelauto also provides data on the downstream processing of cars, as the aggregated output of the different processing installations to which cars and car parts are distributed after depollution of vehicles. The data are Belgian numbers, but these can be taken over as there is no reason to suppose that these would be substantially different for Flanders[37]. A discrimination is made between reuse, recycling, energetic valorization and landfill. The numbers are shown in Figure 23. Following a European directive, recycling of cars was been given a target of 95% in terms of ‘useful application’ (including energetic valorization), explaining the strong increase in these overall numbers in the graph over the years; the target has been met. Both the categories energetic valorization and landfill have decreased over the years, while reuse has increased.

[36] Given the fact that this database is based on license plates instead of on VINs, it does not provide any direct evidence on whether a car has become EoL. EoL cars could only be extracted from the database in a very indirect way, for instance by selecting only cars above a certain mileage for which at the same time there have not been updates over the past few years. Anyway the obtained value for average mileage would have a broad confidence interval.

[37] The downstream processing installations processing cars or car parts from Flanders, Brussels and the Walloon region are probably the same ones in many cases.

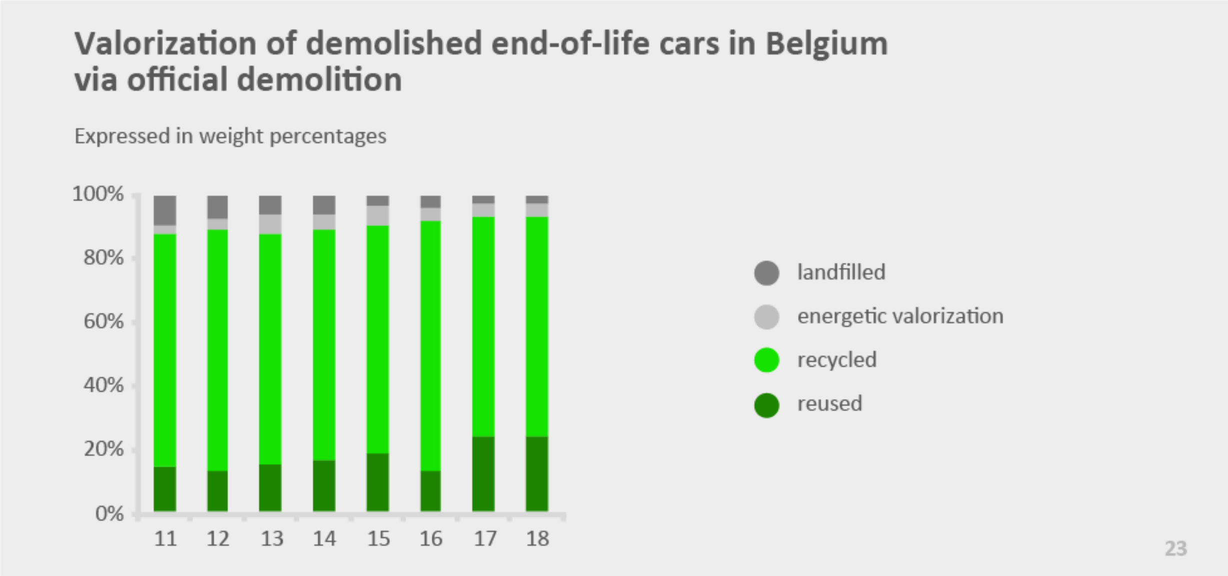


Figure 23: Valorization of demolished EoL cars via official demolition in Belgium expressed in weight percentages.

3.3 A circular economy monitor for mobility

In the previous chapter the available data in the context of mobility and materials that could be retrieved at the different instances have been presented in much detail. In this chapter a further selection of these data will be made in order to construct a CE monitor that reveals the dimension of the materials behind the mobility system. The selection has been based on aspects like the way in which material and environmental impacts have been represented by the data, data quality and possible conclusions that can or cannot be drawn from datasets. Such aspects have been discussed already to some extent in the previous sections, and the respective conclusions are taken into the interpretations of the indicators selected for the monitor.

One particular element for the development of indicators that has not been discussed above is the choice between showing absolute data or relative data, for example dividing by population (per capita or per household) or GDP (intensity, or productivity in the inverse way). It is important to show absolute indicators in the first place, as neither material depletion nor environmental impacts will be less intense when spread over more people or more economic activity. Relative data are easier to compare internationally as they take into account the size of the region in terms of population or economic activity. Per capita or per household indicators are valuable because they show relative progress in those cases where demographic developments may hide certain developments. When the focus is on businesses or sectors, intensity or productivity indicators can be valuable to reflect on the efficiency in terms of materials. On the downside, such indicators have the risk of focusing on relative instead of absolute progress.

The current selection of data for materials and mobility into a set of CE indicators is presented in Figure 24.

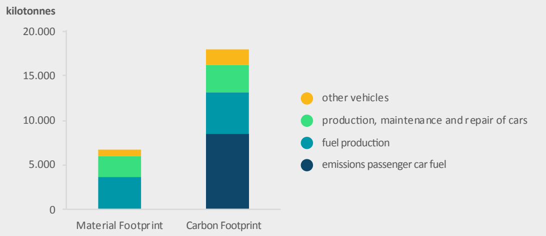
The CE monitor
for person mobility and transport

Figure 24: (all data have been presented in the previous sections)

CE CENTER CIRCULAR ECONOMY
POLICY RESEARCH CENTER

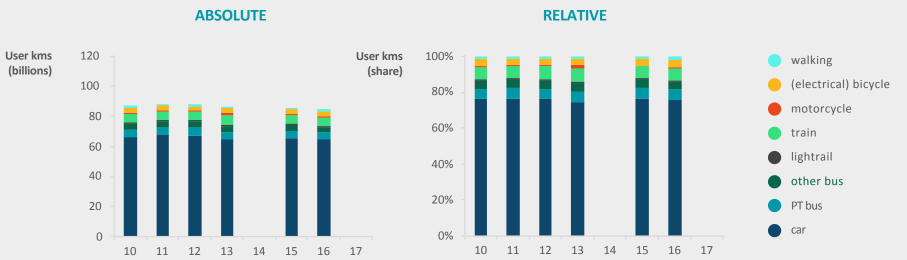
FOOTPRINT

Material and Carbon Footprint of person transport



SYSTEM SIZE

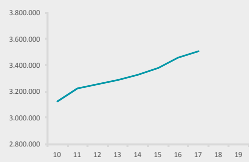
Modal split in person kilometers



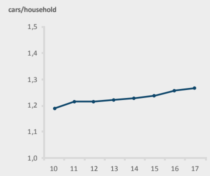
PRODUCT GROUPS FULFILLING THE NEEDS

CARS

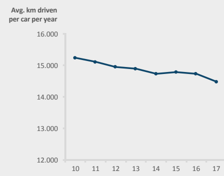
Total amount



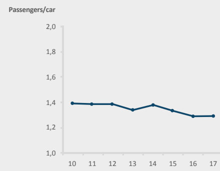
Cars per household



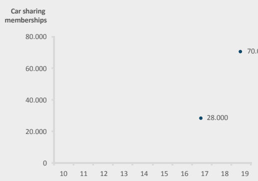
Use intensity



Use efficiency

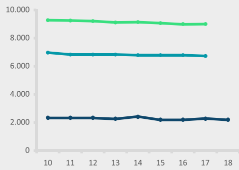


Car sharing uptake

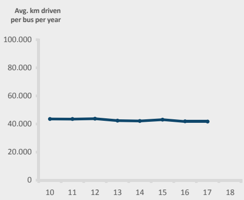


BUSES

Total amount

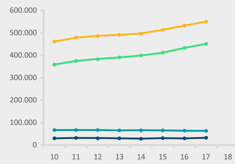


Use intensity

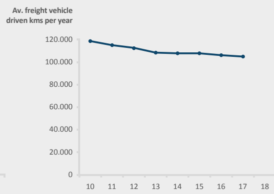


TRUCKS

Total amount

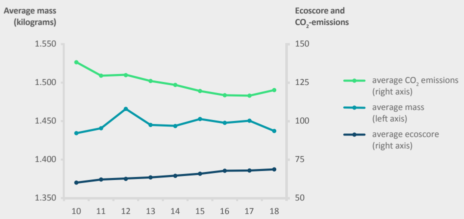


Use intensity

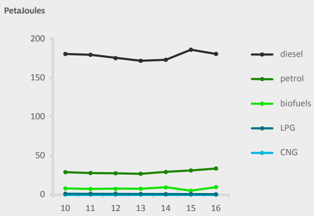


LIFE CYCLE OF VEHICLES

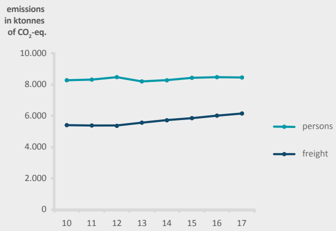
Emissions and Ecoscore of new cars



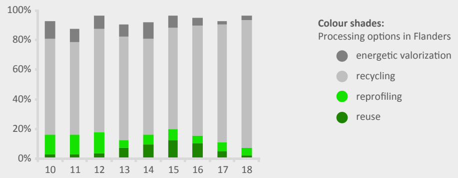
Fuel type and use



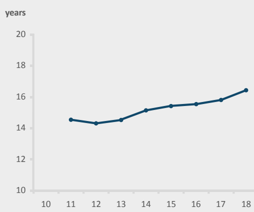
Total emissions



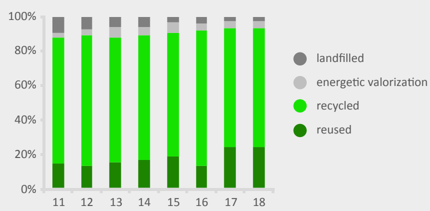
Valorization of old tyres



Age of cars at end of life



Valorization of end-of-life cars



For the considered time range, 2010 was chosen as a starting year, in order to have a substantial range of time, and for a number of data sources no data were immediately available or accessible before 2010. For this year the most recent material and carbon footprint numbers are available, and these appear on top of the mobility monitor functioning as the bridge with the macro level of the CE monitor (which is not further discussed in this report – see Raes et al., 2020), being direct disaggregations from the overall material and carbon footprints that will appear as macro indicators. **The material and carbon footprints of mobility are huge: they comprise 10 and 20% of the respective footprints of household consumption** [Raes et al., 2020; Vercalsteren et al., 2017; Christis et al., 2019a]. If calculated per capita, the material footprint of mobility comes down to roughly 1 tonne per inhabitant and the carbon footprint on 3 tonnes per inhabitant. The very large share of fuels for cars is striking in these numbers.

Next, the modal split based on the amount of passenger kilometers traveled is shown, in order to show the size of the mobility need system. As explained before, this is important to consider with respect to the link between the CE and the planetary boundaries. Overall, ca. **85 billion passenger kilometers are traveled yearly**. The large proportion of cars in this number is striking, although not unexpected, with a value around **65 billion passenger kilometers, coming down to ca. 75% of the total**. The remaining 20 billion kilometers are more or less equally distributed over four modes of transport: PT buses, other buses, trains and the sum of lightrail, motorcycle, bicycle and walking. Neither the absolute numbers nor the ratios between the modes have substantially changed over the years. It hence seems that the absolute demand has stagnated; if considered per capita, a decrease would be noticed. In the next section of the monitor, cars will have a prominent position, given the domination of transport by cars, the huge impacts associated with cars and also the amount of data available.

The next section in the monitor summarizes the way in which product groups are used to fulfill needs:

- The current number of cars is above 3,5 million units, and this number has been ever increasing over the years, with an increase of ca. 10% since 2010, the earliest year shown here. This increase is even visible in the number of cars per household, which has increased from 1,19 to 1,27 units. The average amount of kilometers driven per car per year has decreased from a value over 15.000 in 2010 to ca. 14.500 in 2017. The average amount of passengers in a car seems to have decreased from 1,4 to 1,3 over the same period. The popularity of car sharing increased strongly in recent years, but its occurrence cannot be linked yet to impacts on amounts of cars and car use. In summary, year after year **the same overall demand for car mobility is delivered by an increasing amount of cars which are not more intensively used neither carry more passengers**. This is in fact quite the opposite from a trend towards CE.
- For buses, the monitor reveals slightly **decreasing numbers both for PT buses and other buses**; the decrease would become even more clear when set against population. In terms of CE, this is not a desirable direction as buses have the potential to fulfill mobility needs with less material demands, at least if they are sufficiently occupied. With respect to this, no reliable data on bus occupancy are available. Interestingly, **PT buses seem to be used three times more intensively than other buses**, although this intensity has decreased over the years.
- Trains were not included given the lack of data; lightrail vehicles and motorcycles are too limited in amounts compared to buses and cars and were hence not included.

- Freight vehicles have been given a place in the monitor, based on the expectation to retrieve these vehicles under the heading mobility, although they rather relate to other systems fulfilling societal needs. This will be discussed more in detail below. The selected indicators reveal the **substantial increase of vans and the decreased use intensity of all freight vehicles**.

Next in the monitor, the indicators focus on aspects connected to the life cycle of vehicles, like mass and environmental performance of new cars on the market, fuel consumption, management of used tyres and valorization of End-of-Life cars. Most datasets refer to passenger cars, with following exceptions: for fuel consumption no separate data for passenger vs. freight transport were retrieved, for tyres truck tyres are included, and the End-of-Life vehicles comprise both passenger cars and vans.

- The monitor reveals that **new cars** entering the market seem to have **slightly increased in weight**. The calculated[38] **environmental performance** of new cars has **steadily increased** with as an exception the increase in CO_2 emissions in 2018.
- The vehicle fleet consumes **huge amounts of fuels**, with diesel on top, followed by petrol. The latter fuel is almost completely on the account of passenger cars (but less than half of this fleet drives on petrol) and can be visualized as a volume of 100 by 100 by 100 meters for the complete fleet of petrol cars. The greenhouse gas emissions of fuel use seem to stagnate, in consistency with the fulfilled demand; the amount is **almost half of the carbon footprint** of mobility.
- Car **tyres**, as major consumables, are **collected with high efficiency**, and only a minor part is not applied in a next use cycle. However, these next cycles come down to a substantial degree of **downcycling**, and **reprofiling or reuse of tyres, which are the most circular applications, seem to have decreased strongly** over the later years of the considered period.
- With respect to the **EoL phase**, the **age of cars** at the moment of demolition has **strongly increased** from over 14 to over 16 years over the considered period. More detailed data on use intensity or environmental performance of these cars could not be provided yet. Valorization of EoL cars takes place with increasing circularity, with **landfilling and incineration decreasing and reuse increasing** over the years.

It is important to note that this CE monitor of mobility only represents the current state of what can be shown already. In the future, when new and more extensive data become available and also mobility would be fulfilled in different ways and with different vehicles compared to today, the monitor will need to be updated. Also, interpretation of single indicators has to be done with much caution. For instance, use intensity of cars has to be evaluated taking into account the total amount of cars and the use of other means of transport (see for instance the hypothetical situation in which cars would be used more intensively at the expense of bus transport).

[38] This is based on Ecoscore data, in which a correction for NO_x emissions has been applied to the theoretical numbers from homologation.

4. Discussion and Conclusion

4.1 Progress towards CE

The conclusions on the current state of CE in the mobility system are clear and striking: huge amounts of materials are involved in the mobility system, and these amounts have increased over time with vehicles growing in amounts and these being used less intensively and efficiently. Moreover, there is no substantial evolution in the modal shift towards public transport (PT) or bicycles, which take less materials compared to persons transported.[39] The popularity of car sharing has strongly increased over the last few years, but it is not possible to conclude anything yet on its impact on car production and use. New cars entering the market do not become lighter although their environmental performance is steadily improving. A large consumption of fuels is connected to car use. Valorization of used tyres comes largely down to substantial downcycling, with decreasing shares of reuse and reprofiling. Valorization of EoL cars via official demolition has improved a lot: amounts of materials landfilled or incinerated have become minimal, and reuse has increased. Cars tend to be kept in use longer, but it is not clear yet whether the mileage at end of life has increased as well, neither to which extent this balances with environmental impacts. ***In summary, the mobility system transports especially materials instead of people. Its current state is far from circular and its evolution seems to continue in the linear direction.***

The focus on passenger cars is prominent in the CE monitor. Passenger car brings by far the highest material impacts versus the amount of passengers transported; also from a CE perspective the modal split towards public, shared and lighter mobility is to be stimulated. ***Cars are relatively easy to track for monitoring***: with almost every operation concerning a car, an administrative action is involved, the data of which are managed largely within the public domain and are in many cases accessible, at least on an aggregated level. ***Still, a number of data that are available did not become accessible within the scope of this work, like use data in car sharing, and total amounts, environmental performance and mileage of EoL cars, and more detailed data on car production. In some cases proxy indicators have been used*** in order to give at least some reflection of progress until better data may become available. For car sharing the amounts of memberships have been included, and for EoL cars the use intensity has been approximated by their average age. However, there are risks involved with the use of proxy data. In the case of car sharing, the indicator on memberships may be used in a wrong way by stimulating memberships as such, without any consideration whether current practices of car sharing are really contributing to having less materials or a reduction in the mobility demand. Data on the total amount of EoL vehicles becoming available yearly are not available. The available numbers of EoL cars delivered in official demolition centers have not been included in the monitor as any trends in this number may be misinterpret without this reference number.

While the focus on the large amounts of materials consumed in the system is already very valuable on itself, the indicators in fact do not show direct ways to steer the system in a more circular direction. For instance, there is no indicator that reflects the way how to increase PT

[39] For PT this holds when occupancy is sufficiently high. For bicycles, the recent increase of speed pedelecs, also for commuting, has not been included in the current study but needs to be followed up (see e.g. http://www.fietsberaad.be/Kennisbank/Bijlagen/FietsDNA_2018_web.pdf).

use. A major (and on the short term irreversible) lock-in for the mobility system is the urban sprawl existing in Flanders. This could be reflected to some extent using mobiscore data.[40]

Furthermore, the monitor reveals two important aspects. First, an important ***trade-off has been revealed between prolonging vehicle lifetime versus environmental performance***. This will be further investigated in the running research of the policy research center. Ideally the monitor will be able to show in the future this balance between environment and material use. Next, the monitor can be used to illustrate what could happen in terms of material consumption with the upcoming ***transition towards electrical vehicles***. If this transition comes down to ***a simple replacement of current fossil fuel driven vehicles, the mobility demand would still be met with high numbers of cars*** that are used with low intensity and efficiency, leading to the same high material demands[41] in first instance (see also Christis and Vercalsteren, 2019). Besides, the monitor will need to be adapted to accommodate the change in dependency on oil towards critical raw materials in engines and batteries. The management of these devices will need to be monitored in order to reflect the extent to which these critical materials will be maintained within the system. In the context of a future autonomous mobility, a major parameter to monitor will be the management of the fleet, leading to very high occupancies and a minimal amount of idle vehicles in order to really reach a system with a lower impact.

With respect to environmental impacts, the monitor now almost exclusively focuses on greenhouse gas emissions, being very relevant in the context of fighting runaway climate change. It is evident impacts are much broader than climate change, and data on these are to be included in future versions of the monitor. One example are vehicle emission data[42]; other examples are to be found along the complete life cycle, e.g. data relating to mining of (critical) metals or to dust production from wear of tyres etc.

4.2 Fulfillment of societal needs as a basis for monitoring

The compilation of this mobility monitor has been the first elaboration of the concept of the fulfillment of societal needs that has been developed before [Alaerts et al., 2019a] with the aim of delivering a more direct feedback to policy, this by combining information from the macro to the micro level. At the start of this development, the expectation was that the mobility system would provide a relatively easy start, given the expected amounts of available data and the quite specific preliminary ideas on the development of indicators [Alaerts et al., 2019b]. This expectation proved to be true to a large extent, especially with respect to passenger cars: ***a lot of data are openly available, and they allowed to build up a story from a high level, connecting to macro indicators, to a more detailed level.*** In the monitor a number of elements at a smaller scale are given an explicit position, like car sharing, tyres, recycling of cars and properties of new cars entering the market. These do not substantially affect the overall material impact of mobility yet, but have the potential to do so when evolutions towards the CE will become more apparent.

[40] Available via https://mobiscore.omgeving.vlaanderen.be/. Given the connection to the built environment, an indicator like the average mobiscore could be considered to figure in the housing system in the eventual CE monitor.
[41] Or even higher, as electrical vehicles tend to be more heavy.
[42] For instance MIRA provides indicators on emissions of the air polluents NO_x, NMVOC, $PM_{2,5}$ and SO_2.

The focus on systems to fulfill societal needs is a ***footprint perspective with a lot of attention for consumption.*** Following aspects are to be highlighted in this context:

- The development of this CE monitor aligns well with the new CE Action Plan of the European Commission that clearly points to further development of consumption- and footprint-based indicators and that gives a lot of attention to the life cycle of products.
- There have been repercussions for the ***selection of data*** to develop indicators. For instance for vehicle and passenger kilometers, two different kinds of data appeared to exist: one set based on consumption, another one based on territory. Both kinds of data have their value in terms of mobility policy; for this CE monitor the data based on consumption were the more logical one.
- With respect to a previously identified concern that the actors producing goods and services may not easily recognize their possible roles in the CE transition due to the chosen perspective [Alaerts et al., 2019b], a few ***clear links with activities of companies are nevertheless effectively included***, like car sharing, car recycling and even car production (although the decision centers of such companies are not located in Flanders). These logically fill in the places for circular business models and the lifecycle perspective, as provided in the concept of the monitor. Moreover, freight transport has been given a major place within the mobility monitor. For a strict interpretation of systems fulfilling societal needs, freight transport should be more logically positioned in each of the other need systems (i.e. food transport would have to be allocated in nutrition). However, for clarity and as it would be rather strange not to retrieve freight transport below the theme mobility, an attempt to monitor the resource efficiency of the Flemish transport sector has been included. ***As a consequence, the heading of this part of the CE monitor was expanded to 'person mobility and transport'.***
- The case of company cars was treated in the same way in this context, with most of them rather belonging to other need systems. It would be peculiar to treat these cars separately, as many of them are in reality not very differently used compared to privately owned cars, or they can be used in the context of the operation of a company during working time and in a private context outside working time. Also, making this distinction in the monitor may not necessarily lead to clearer insights.[43]

Another aspect to discuss are ***possible linkages with other need systems***. For instance with respect to roads and infrastructure, an argument could be built to include these within mobility, as roads and infrastructure are in place for facilitating mobility. On the other hand, given the characteristics of the material flows involved, it may be more logical to deal with roads and infrastructure in terms of housing – also given the fact that a lot of building waste is recycled into roads. For now, the choice has been made ***not to include roads and infrastructure*** in mobility. Other points where the discussion on linkages between need systems became apparent were a suggestion to include mobiscore data (see above) and the inclusion of freight transport (see previous paragraph).

Next, the ambition was to provide indicators from macro to micro, including relations between these levels. While it was clear from the onset that providing a full disaggregation would not be feasible in the monitor, the approach to compile this monitor was to add step by step increasing

[43] Leasing companies often have their administrative headquarters either in Flanders or in Brussels, and they can and will easily move if the regulation changes in favor of a particular region. Also, such companies also provide cars to users in other regions. This may lead to peculiar results when monitoring from the perspective of Flanders.

levels of detail in the selection of indicators. On top of the CE monitor shown in Figure 24 the material and carbon footprint appear together with a measure of the size of the system, coming down to the headline indicators of the mobility system. Next, the different product groups playing major roles in the fulfillment of needs in the mobility system have been listed. At the bottom, more detail has been added by focusing on the life cycle of products (in which cars are most prominent). While this focus may be reminiscent of the perspective to follow when developing micro indicators, none of the indicators featuring in the CE monitor can be considered as a micro indicator as such. Indeed, such indicators would have to focus on particular products and could for instance serve to compare the circularity of one particular car versus another one. In order to work with such indicators, a very high level of detail on the production process of vehicles would for instance be required. This was not feasible within the timeframe of this project. The closest connection to micro indicators in the CE monitor would perhaps be the data on recycling of tyres and EoL cars, as these are in fact aggregations from the outputs of different company operations. In conclusion, ***the ambition to incorporate the micro level was only met to a limited extent in the monitor, but the focus on product groups and on the life cycle of products*** (the so-called 'meso' level as denoted before) ***offers already a view on a set of smaller-scale aspects in which the progress towards a CE will become visible sooner***. For instance if cars would last longer and the effective reuse and recycling would increase, this would at first become visible immediately in micro indicators, if available. In next instance, this developments would be picked up by indicators on the age of cars and on recycling efficiency. Eventually, the demand of virgin raw materials will decrease, but this will only be visible in a much later instance in the respective footprint data. The expectation is that when it would become possible to include detailed data on car production, the relation between indicators at the different levels would become even more apparent.

In summary, the experience gained with building up this part of the monitor will be very helpful when filling the next systems to fulfill societal needs in the monitor. A major element is maintaining a ***balance between the principle of a footprint perspective and some pragmatism in what logically belongs together. Not all aspects will clearly fit under one single need system***; most important will be that such aspects are identified in the first place, and next put in the more logical need system in terms of the CE transition. The difficulties in obtaining detailed data that allow to develop micro indicators for the CE monitor may appear equally (or even more) ambitious in other need systems; most important is to ***gather those data*** that offer a view on aspects of the CE transition ***in which progress will become visible sooner***.

4.3 Data gathering

A major added value of the monitor is in ***directly bringing together facts on vehicles and their use with a focus on the material repercussions*** of mobility demand. Such an overview cannot be consulted easily elsewhere, as ***the data are spread over a large range of sources***: not only the mobility departments at the Flemish and Federal level have been consulted, but also instances like the Flanders Environment Agency, the Flemish department of environment, the Flemish waste agency, the Federal Planning Bureau and Statistics Flanders, VITO, and next to this data from EPR organizations responsible for the management of EoL cars and tyres. As a consequence, ***a large diversity in kinds of data was encountered***: survey data, odometer data, data from counting devices, data from model calculations, data as lumped performances of company processes etc.

For cars, almost all information is essentially present within these data sources. This is connected to the administrative duties accompanying any operation involving a car. Only ***one major gap was found: the possibility to sell a private car without any obligation to provide any document or registration*** exists,[44] and this contributes to the situation that there is ***no full traceability of cars*** in Flanders or Belgium, leading to not having data of the total number of EoL cars becoming available yearly. This also connects to the fact that the car registration database DIV is not based on VINs but on license plates. Moreover, it did not prove possible to get access to all available data. For instance, it would be in theory perfectly possible to obtain numbers on current use of shared cars and on mileages of EoL cars, but ***bottlenecks were encountered at the side of protection of privacy and commercial position*** with the actors involved. If full traceability is to be strived for within the administration,[45] this would imply an increased accessibility of data, which will also lead to an improved CE monitoring.

With respect to ***PT vehicles***, the monitor offers a comprehensive overview of amounts and use, compiled from four different sources which each on their own only provides fragmented data. ***The major gap was the determination of passenger kilometers and occupancies***. The bottlenecks are the particularities of ticketing systems in PT buses and for trains the Belgium-oriented operation and the lack of data on the train fleet. In order to improve data here, the possible disclosure of the business position of the involved companies may be a bottleneck, as the aimed indicators may come close to monitoring and hence revealing their commercial positions.

Towards the future, futher action is to be undertaken to ***gather more detailed data*** on car production, in order to track progress towards the CE at an even higher level of detail. Also, indicators focusing on the materials in ***low-emission vehicles***, e.g. electrical or hydrogen, will need to be included. This will imply a focus on ***data gathering on the composition and management of batteries***[46] ***and engines*** *(also in bicycles)* and the critical raw materials inside, and a higher level of detail in the data will be required for this. Another development could be to develop economic indicators on expenditures on mobility or the average cost of transportation by cars. While the transition to a circular low carbon mobility system will require large investments, it would interesting to see how this system could in next instance save investments and expenditures.

4.4 Data governance

The smooth availability of data on mobility has allowed to focus as well on aspects pertaining to data within this project. Hence some recommendations can be made on how to organize data gathering in the context of CE monitoring. These ideas pertain in the first place to the data landscape of mobility, but the implications go beyond this:

- It became clear soon that ***within the administration there is no central point where data with a focus on products and materials are centrally collected and managed***. While this

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[44] This besides the scrapping of the license plate, for which DIV has to be involved and directly leading to ending the car taxation.

[45] In order to install full traceability in the administration, additional action is needed to convert existing legislation on this aspect into execution. This has been advocated by several of the consulted actors.

[46] Stimulating transparency of the battery product chain is contained in the European circular economy action plan. Febelauto will be in charge for the EPR duties with respect to batteries of electrical cars.

does not pose a problem in itself, it appeared that every organisation gathers and manages data on mobility for its own purposes. This may lead to situations that different datasets are sometimes not compatible or have very different perspectives. A very clear example was found in the passenger kilometers of cars: these can be monitored from road counting devices with the eventual purpose of delivering a number on the territorial emissions of Flanders, or from odometer data from a perspective of Flemish cars. In fact, a lot of efforts behind the current paper went into understanding these different perspectives and aligning data for the purpose of monitoring CE.

- With respect to improve accessibility of data, ***there might be easier access*** to the DIV database ***if requests for data could be given a more obligatory character and/or be supported by a coalition*** of involved instances.
- ***Towards companies, federations and EPR organizations, most probably a narrative is needed showing the alignment between the CE transition, its monitoring and the particular missions of these entities*** in order to obtain more detailed data, for instance on car production. For instance if indicators are able to show their progress, it may be interesting to have them appearing in the monitor. This most probably will require an approach to resolve commercial and legal bottlenecks as well. All of this may become even more so in the future contexts of electrical and autonomous vehicles. For instance if passenger kilometers are to be monitored in a system of autonomous vehicles, data on detailed trips made by passengers may become open. For critical raw materials in electrical cars, data are connected to intellectual property and technological secrets. In this context a product passport for cars may eventually appear, the data of which will be highly valuable for monitoring materials and use of vehicles.

For the future maintenance and development of the CE monitor, it will be important to consider where this collection of data would be managed, how updating and expanding could happen and how accessibility of data could be improved. It will be important to consider a data governance that enables bringing together and manage data from different stakeholders in a safe and collaborative way.

List of references

Alaerts, L., Van Acker, K., Rousseau, S., De Jaeger, S., Moraga, G., Dewulf, J., De Meester, S., Van Passel, S., Compernolle, T., Bachus, K., Vrancken, K., Eyckmans, J. (2019a). Towards a circular economy monitor for Flanders: a conceptual basis. Publication nr 4 of the CE Policy Research Centre nr 4, available online via www.vlaanderen-circulair.be/en/summa-ce-centre/publications/towards-a-circular-economy-monitor-for-flanders-a-conceptual-basis (accessed on April 6, 2020)

Alaerts, L., Van Acker, K., Rousseau, S., De Jaeger, S., Moraga, G., Dewulf, J., De Meester, S., Van Passel, S., Compernolle, T., Bachus, K., Vrancken, K., Eyckmans, J. (2019b). Towards a more direct policy feedback in circular economy monitoring via a societal needs perspective. Resources, Conservation and Recycling, 149, p. 363-371. doi.org/10.1016/j.resconrec.2019.06.004

Carmen R., Rousseau S., Eyckmans J., Chapman D., Van Acker K., Van Ootegem L., Bachus K. (2019). Car sharing in Flanders. Publication nr 9 of the CE Policy Research Centre, available online via https://ce-center.vlaanderen-circulair.be/nl/publicaties/publicatie-2/9-car-sharing-in-flanders (accessed on April 6, 2020).

Christis, M., Van der Linden A., Vercalsteren A. (2019a). Materialenimpact van de Vlaamse consumptie – de Materialenvoetafdruk, studie uitgevoerd in opdracht van de OVAM. VITO, Mol.

Christis, M., Vercalsteren, A. (2019b). Impact of Circular Economy on achieving the climate targets: case mobility. Publication nr 6 of the CE Policy Research Centre, available online via https://ce-center.vlaanderen-circulair.be/nl/publicaties/publicatie-2/6-impact-of-circular-economy-on-achieving-the-climate-targets-case-mobility (accessed on April 6, 2020)

De Caevel, B., Huppertz, T. (2017). Mise à jour de la composition moyenne des VHU en Belgique et au Luxembourg. Study by rdc environment commissioned by Febelauto.

Dierick, K. (2018). Milieubeleidsovereenkomst afvalbanden, Evaluatierapport 2016-2017. OVAM report.

Kwanten, M. (2018). Kilometers afgelegd door Belgische voertuigen in 2017. Publicatie van Directoraat-generaal Duurzame Mobiliteit en Spoorbeleid, available online via https://mobilit.belgium.be/nl/mobiliteit/mobiliteit_cijfers/kilometers_door_belgische_voertuigen (accessed on April 6, 2020)

Material Economics (2018). The Circular Economy, a Powerful Force for Climate Mitigation. Transformative innovation for prosperous and low-carbon industry. Available online via https://media.sitra.fi/2018/06/12132041/the-circular-economy-a-powerful-force-for-climate-mitigation.pdf (accessed on April 6, 2020)

Raes W., Van Pelt A., Smeets K., Wante J., Mouligneau B., Alaerts L. (2020). Naar een circulaire economie monitor voor Vlaanderen: een eerste invulling door OVAM. OVAM, publication number 2020. 135 pp.

Vercalsteren A., Boonen K., Christis M., Dams Y., Dils E., Geerken T. & Van der Linden A. (VITO), Vander Putten E. (VMM) (2017). Koolstofvoetafdruk van de Vlaamse consumptie. Studie uitgevoerd in opdracht van de Vlaamse Milieumaatschappij (VMM), MIRA. VMM, Aalst.

Appendix: data, sources and calculations

All details with respect to data sources, data used in the figures shown throughout the report and own calculations and combinations of data are available in the following datafile. Screenshots are provided on the following pages.

data, sources and calculations.xlsx

data	source	calculation	unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	used in Figure
material footprint: fuel production	VITO, MIRA/VMM, OVAM		kilotonnes of materials	3689										2
material footprint: production, maintenance and repair of cars	VITO, MIRA/VMM, OVAM		kilotonnes of materials	2347										2
material footprint: other	VITO, MIRA/VMM, OVAM		kilotonnes of materials	693										2
carbon footprint: emissions passenger car fuel	VITO, MIRA/VMM, OVAM		kilotonnes of CO_2-equivalents	8433										2
carbon footprint: fuel production	VITO, MIRA/VMM, OVAM		kilotonnes of CO_2-equivalents	4794										2
carbon footprint: production, maintenance and repair of cars	VITO, MIRA/VMM, OVAM		kilotonnes of CO_2-equivalents	2993										2
carbon footprint: other vehicles	VITO, MIRA/VMM, OVAM		kilotonnes of CO_2-equivalents	1788										2
passenger cars: number	FOD M&T		-	3126350	3223994	3255160	3286298	3325621	3381224	3460169	3507705			3a
passenger cars: number	FPB		-	3182387	3230141	3253075	3284462	3322382	3379602	3458905	3506643			3a
passenger cars: number	MORA		-	3149996	3200256	3223989	3254170	3296689	3347610	3405291	3455865			3a
passenger cars: number	MIRA / Ecoscore		-	3107303	3156116	3219103	3254531	3304876	3356478	3412017	3449825			3a
passenger cars: number	Statistiek Vlaanderen		-	3126050	3223690		3282245	3320409	3364863	3447947	3494829	3541546	3569202	3a
population Flanders	Statistiek Vlaanderen		-	6251983	6251983	6350765	6381859	6410705	6410705	6477804	6516011			
amount of cars per capita	FOD M&T, Statistiek Vlaanderen	line 10 / line 15	-	0,50	0,52	0,51	0,51	0,52	0,53	0,53	0,54			3b
number of households in Flanders	Statistiek Vlaanderen		-	2629733	2652271	2675085	2691319	2707723	2731319	2748019	2769259	2792444	2815769	
amounts of cars per household	FOD M&T, Statistiek Vlaanderen	line 10 / line 17	-	1,19	1,22	1,22	1,22	1,23	1,24	1,26	1,27			3b
passenger cars: vehicle kilometers per year	FOD M&T		billion kilometers	47,7	48,7	48,7	48,3	48,2	49,0	49,9	49,7			4
passenger cars: vehicle kilometers per year	Dept MOW		billion kilometers	44,5	45,2	45,8	43,9	44,6	45,3	45,9	46,0			4
passenger cars: average distance driven per vehicle per year	FOD M&T		kilometers	15242	15104	14948	14903	14727	14779	14743	14483			5
number of car sharing memberships	autodelen.net		-								28000		70000	6
passenger cars: occupancy	Promovia (Dept MOW)	line 26 / line 20	-	1,39	1,39	1,39	1,34	1,38	1,34	1,29	1,29			7
passenger cars: occupancy	OVG (Dept OMG)		-	1,84	1,84	1,82	1,84		1,80	1,76	1,78			7
passenger cars: person kilometers per year	FOD M&T, Promovia	line 19 * line 23	kilometers	66,3	67,6	67,6	64,8	66,5	65,4	64,4	64,1			8, 12b
passenger cars: person kilometers per year	Promovia (Dept MOW)		kilometers	61,9	62,8	63,6	58,9	61,5	60,5	59,2	59,4			8
passenger cars: person kilometers per year	Statistiek Vlaanderen		kilometers				62,1	64,9	63,8	62,6	62,9			8
passenger car: person kilometers per year	OVG (Dept OMG)	line 70 + line 71	billion kilometers	58,6	59,8	57,9	69,2		68,9	59,6	63,5			8, 12a
passenger cars: person kilometers per year	FOD M&T, OVG	line 19 * line 24	kilometers	87,9	89,6	88,7	88,7		88,3	87,9	88,6			8
all buses: number	FOD M&T		-	9281	9.228	9.183	9.125	9.151	9.048	8.995	8969			9
PT buses: number	De Lijn		-	2333	2360	2326	2275	2393	2262	2240	2274	2245		9
other buses: number	FOD M&T, De Lijn	line 30 - line 31	-	6948	6868	6857	6850	6758	6786	6755	6695			9
lightrails: number	De Lijn		-	359	359	362	369	371	392	399	418	407		9
all buses: vehicle kilometers per year	FOD M&T	line 38 * line 30 / 1E9	billion kilometers	0,400	0,400	0,396	0,385	0,382	0,385	0,371	0,372			9
PT buses: vehicle kilometers per year	De Lijn		billion kilometers	0,210	0,208	0,200	0,193	0,191	0,191	0,190	0,187	0,185		9
other buses: vehicle kilometers per year	FOD M&T, De Lijn	line 34 - line 35	billion kilometers	0,190	0,191	0,195	0,192	0,191	0,194	0,181	0,185			9
lightrails: vehicle kilometers per year	De Lijn		billion kilometers	0,016	0,016	0,016	0,017	0,017	0,017	0,017	0,017	0,016		9
all buses: average distance driven per vehicle per year	FOD M&T		kilometers	43110	43.309	43.084	42.214	41.792	42.555	41.272	41446			9
PT buses: average distance driven per vehicle per year	De Lijn	line 35 / line 31 * 1E9	kilometers	90021	88306	86088	84840	79990	84352	84824	82206	82603		9
other buses: average distance driven per vehicle per year	FOD M&T, De Lijn	line 36 / line 32 * 1E9	kilometers	27358	27847	28497	28057	28266	28623	26830	27601			9
lightrails: average distance driven per vehicle per year	De Lijn	line 37 / line 33 * 1E9	kilometers	44239	43197	43399	45452	44482	42930	42101	40800	40523		9
all buses: person kilometers per year	MIRA, OVG	line 43 + line 44	billion kilometers	9,11	9,02	9,18	9,15		9,31	8,79				9
PT buses: person kilometers per year	MIRA, OVG	line 46 - line 73	billion kilometers	4,98	4,88	4,93	5,20		5,20	5,11				9, 12b
other buses: person kilometers per year	MIRA		billion kilometers	4,13	4,14	4,25	3,95	3,98	4,11	3,68				9, 12b
lightrails: person kilometers per year	OVG (Dept OMG)		billion kilometers	0,34	0,41	0,32	0,43		0,34	0,34	0,45			9, 12b
PT buses and lightrails: person kilometers per year	MIRA		billion kilometers	5,32	5,29	5,25	5,63	5,55	5,54	5,45				
all buses: occupancy	FOD M&T, MIRA, OVG	line 42 / line 34	-	22,8	22,6	23,2	23,8		24,2	23,7				9
PT buses: occupancy	FOD M&T, MIRA, OVG, De Lijn	line 43 / line 35	-	23,7	23,4	24,6	26,9		27,3	26,9				9
other buses: occupancy	FOD M&T, MIRA, De Lijn	line 44 / line 36	-	21,7	21,6	21,8	20,6	20,8	21,2	20,3				9
lightrails: occupancy	De Lijn, OVG	line 45 / line 37	-	21,1	26,6	20,6	25,6		20,0	20,0	26,6			9
trains: person kilometers per year	MIRA, Statistiek Vlaanderen		billion kilometers	6,19	6,44	6,47	6,51	6,59	6,23	6,07	6,3	6,53		10, 12b
trains: person kilometers per year	OVG (Dept OMG)		billion kilometers	5,85	5,91	6,55	5,16		4,24	9,43	5,06			10
walking: fraction of total person kilometers	OVG (Dept OMG)		%	1,34	0,99	1,46	1,07		1,19	1,65	1,24			
cycling: fraction of total person kilometers	OVG (Dept OMG)		%	4,46	3,48	3,19	3,8		2,7	3,82	3,33			
light motorcycle: fraction of total person kilometers	OVG (Dept OMG)		%	0,42	0,2	0,16	0,35		0,08	0,1	0,1			
motorcycle (or passenger): fraction of total person kilometers	OVG (Dept OMG)		%	0,4	0,54	0,53	1,69		0,13	0,45	0,3			
car driver: fraction of total person kilometers	OVG (Dept OMG)		%	51,16	46,34	46,04	57,29		47,46	47,87	44,65			
car passenger: fraction of total person kilometers	OVG (Dept OMG)		%	24,09	20,25	18,55	23,29		20,11	19,73	18,42			
bus: fraction of total person kilometers	OVG (Dept OMG)		%	2,53	1,97	2,2	1,92		1,83	2,94	1,34			
lightrail/metro: fraction of total person kilometers	OVG (Dept OMG)		%	0,43	0,46	0,36	0,5		0,33	0,38	0,45			
train: fraction of total person kilometers	OVG (Dept OMG)		%	7,51	6,58	7,3	6,01		4,16	10,69	5,02			
coach: fraction of total person kilometers	OVG (Dept OMG)		%	3,19	2,01	2,22	1,05		2,07	2,81	1,17			
other: fraction of total person kilometers	OVG (Dept OMG)		%	4,47	17,17	17,88	3,03		19,56	9,23	23,64			
electrical bicycle: fraction of total person kilometers	OVG (Dept OMG)		%	0	0	0	0		0,38	0,30	0,34			
total person kilometers per day	OVG (Dept OMG)		billion kilometers	0,21	0,25	0,25	0,24		0,28	0,24	0,28			
walking: person kilometers per year	OVG (Dept OMG)	line 65 * line 53 * 365 / 100	billion kilometers	1,04	0,89	1,31	0,92		1,21	1,46	1,25			11, 12a, 12b
cycling: person kilometers per year	OVG (Dept OMG)	line 65 * line 54 * 365 / 100	billion kilometers	3,48	3,13	2,86	3,27		2,75	3,37	3,35			
light motorcycle: person kilometers per year	OVG (Dept OMG)	line 65 * line 55 * 365 / 100	billion kilometers	0,33	0,18	0,14	0,30		0,08	0,09	0,10			
motorcycle (or passenger): person kilometers per year	OVG (Dept OMG)	line 65 * line 56 * 365 / 100	billion kilometers	0,31	0,49	0,48	1,45		0,13	0,40	0,30			
car driver: person kilometers per year	OVG (Dept OMG)	line 65 * line 57 * 365 / 100	billion kilometers	39,87	41,63	41,30	49,23		48,41	42,22	44,97			
car passenger: person kilometers per year	OVG (Dept OMG)	line 65 * line 58 * 365 / 100	billion kilometers	18,77	18,19	16,64	20,01		20,51	17,40	18,55			
bus: person kilometers per year	OVG (Dept OMG)	line 65 * line 59 * 365 / 100	billion kilometers	1,97	1,77	1,97	1,65		1,87	2,59	1,35			
lightrail/metro: person kilometers per year	OVG (Dept OMG)	line 65 * line 60 * 365 / 100	billion kilometers	0,34	0,41	0,32	0,43		0,34	0,34	0,45			
train: person kilometers per year	OVG (Dept OMG)	line 65 * line 61 * 365 / 100	billion kilometers	5,85	5,91	6,55	5,16		4,24	9,43	5,06			12a
coach: person kilometers per year	OVG (Dept OMG)	line 65 * line 62 * 365 / 100	billion kilometers	2,49	1,81	1,99	0,90		2,11	2,48	1,18			
other: person kilometers per year	OVG (Dept OMG)	line 65 * line 63 * 365 / 100	billion kilometers	3,48	15,42	16,04	2,60		19,95	8,14	23,81			12a
electrical bicycle: person kilometers per year	OVG (Dept OMG)	line 65 * line 64 * 365 / 100	billion kilometers	0,00	0,00	0,00	0,00		0,39	0,26	0,34			
(electrical) bicycle: person kilometers per year	OVG (Dept OMG)	line 67 + line 77	billion kilometers	3,48	3,13	2,86	3,27		3,14	3,63	3,70			11, 12a, 12b
motorcycle: person kilometers per year	OVG (Dept OMG)	line 68 + line 69	billion kilometers	0,64	0,66	0,62	1,75		0,21	0,49	0,40			11, 12a, 12b
PT bus + bus + lightrail/metro: person kilometers per year	OVG (Dept OMG)	line 72 + line 73 + line 75	billion kilometers	4,79	3,99	4,29	2,98		4,31	5,41	2,98			12a
passenger cars: person kilometers per year	see calculation	line 25 / (sum of lines 25, 43, 44, 45, 51, 66, 78, 79)	%	76%	77%	76%	75%		76%	76%				12c
PT buses: person kilometers per year	see calculation	line 43 / (sum of lines 25, 43, 44, 45, 51, 66, 78, 79)	%	6%	6%	6%	6%		6%	6%				12c
other buses: person kilometers per year	see calculation	line 44 / (sum of lines 25, 43, 44, 45, 51, 66, 78, 79)	%	5%	5%	5%	5%		5%	4%				12c
lightrails: person kilometers per year	see calculation	line 45 / (sum of lines 25, 43, 44, 45, 51, 66, 78, 79)	%	0%	0%	0%	0%		0%	0%				12c
trains: person kilometers per year	see calculation	line 51 / (sum of lines 25, 43, 44, 45, 51, 66, 78, 79)	%	7%	7%	7%	7%		7%	7%				12c
motorcycle: person kilometers per year	see calculation	line 66 / (sum of lines 25, 43, 44, 45, 51, 66, 78, 79)	%	1%	1%	1%	2%		0%	1%				12c
(electrical) bicycle: person kilometers per year	see calculation	line 78 / (sum of lines 25, 43, 44, 45, 51, 66, 78, 79)	%	4%	4%	3%	4%		4%	4%				12c
on foot: person kilometers per year	see calculation	line 79 / (sum of lines 25, 43, 44, 45, 51, 66, 78, 79)	%	1%	1%	1%	1%		1%	2%				12c
truck transport: tonkilometers per year	MIRA		billion tonkilometers	39,1	36,8	37,6	43,1	41,5	44,7	46,1				13
ship transport: tonkilometers per year	MIRA		billion tonkilometers	6,3	6,7	6,6	6,2	6,2	6,2	6,4				13
train transport: tonkilometers per year	MIRA		billion tonkilometers	3,7	3,8	3,7	3,7	3,7	3,7	3,8				13
vans: number	FOD M&T		-	359802	376.370	383.926	392.875	401.284	414.632	434.053	452037			14
trucks: number	FOD M&T		-	70456	70.590	70.059	68.692	67.825	67.237	66.090	65745			14
lorry cabins: number	FOD M&T		-	33464	33.712	32.966	31.982	31.932	32.240	32.928	34622			14
total road freight vehicles: number	FOD M&T	line 92 + line 93 + line 94	-	463722	480672	486951	493549	501041	514109	533071	552404			14
vans: vehicle kilometers per year	FOD M&T	line 92 * line 100 / 1E9	billion kilometers	6,5	6,5	6,7	6,5	6,7	6,9	7,2	7,4			15
trucks: vehicle kilometers per year	FOD M&T	line 93 * line 101 / 1E9	billion kilometers	1,7	1,6	1,6	1,5	1,5	1,4	1,4	1,4			15
lorry cabins: vehicle kilometers per year	FOD M&T	line 94 * line 102 / 1E9	billion kilometers	2,6	2,5	2,4	2,3	2,2	2,3	2,2	2,3			15
total road freight vehicles: vehicle kilometers per year	FOD M&T	line 96 + line 97 + line 98	billion kilometers	10,7	10,7	10,7	10,3	10,4	10,6	10,9	11,2			15
vans: average distance driven per vehicle per year	FOD M&T		kilometers	17984	17390	17372	16571	16589	16595	16669	16459			16
trucks: average distance driven per vehicle per year	FOD M&T		kilometers	23906	23199	22876	21746	21624	21452	21389	21032			16
lorry cabins: average distance driven per vehicle per year	FOD M&T		kilometers	77143	74764	72819	70563	69991	70126	67867	67519			16
total road freight vehicles: average distance driven per vehicle per year	calculation: sum of above three		kilometers	119033	115353	113067	108880	108204	108173	105925	105010			16
Average mass of new vehicles	Ecoscore		kilogram	1434	1440	1465	1445	1443	1452	1447	1450	1437		17
Average CO2 of new vehicles	Ecoscore		gram per kilometer	138	129	130	126	123	119	117	116	120		17
Average ecoscore of new vehicles	Ecoscore		-	59,8	61,8	62,3	63,4	64,3	65,6	67,5	67,9	68,6		17
fuel use of road transport: petrol	MIRA		PetaJoule	30	29	28	28	30	32	35				18
fuel use of road transport: diesel	MIRA		PetaJoule	180	179	175	172	173	185	180				18
fuel use of road transport: biofuels	MIRA		PetaJoule	9,0	8,7	8,8	8,7	10,5	6,6	11,2				18
fuel use of road transport: LPG	MIRA		PetaJoule	1,3	1,3	1,3	1,1	1,2	1,6	1,6				18
fuel use of road transport: CNG	MIRA		PetaJoule	0,01	0,01	0,01	0,02	0,07	0,11	0,27				18
emissions of person transport	MIRA		kilotonnes of CO_2-equivalents	8308	8360	8499	8225	8315	8467	8505	8476			19
emissions of freight transport	MIRA		kilotonnes of CO_2-equivalents	5408	5392	5377	5574	5732	5871	6029	6157			19
collection rate of tyres in Belgium	Recytyre, via OVAM		%	93	88	97	91	92	97	95	93	97		
fraction of reuse of collected tyres	Recytyre, via OVAM		mass percentage	3,12	3,5	3,57	7,86	10,6	13,02	11,01	5,65	2,45		
fraction of reprofiling of collected tyres	Recytyre, via OVAM		mass percentage	14,31	15,32	15,2	5,96	7,36	7,47	5,17	6,05	5,28		
fraction of recycling of collected tyres	Recytyre, via OVAM		mass percentage	69,95	71,14	71,94	77,21	70,49	70,92	78,81	85,48	89,01		
fraction of energetic valorization of collected tyres	Recytyre, via OVAM		mass percentage	12,62	10,04	9,29	8,97	11,55	8,59	5,01	2,82	3,26		
fraction of reuse of collected tyres within collection rate	Recytyre, via OVAM	line 115 * line 114 / 100	%	3	3	3	7	10	13	10	5	2		20
fraction of reprofiling of collected tyres	Recytyre, via OVAM	line 116 * line 114 / 100	%	13	13	15	5	7	7	5	6	5		20
fraction of recycling of collected tyres	Recytyre, via OVAM	line 117 * line 114 / 100	%	65	63	70	70	65	69	75	79	86		20
fraction of energetic valorization of collected tyres	Recytyre, via OVAM	line 118 * line 114 / 100	%	12	9	9	8	11	8	5	3	3		20
amount of cars scrapped in official demolition centres in Flanders	Febelauto		-		85596	81221	69624	65795	54077	53808	62907	71484		21
average age of cars scrapped in official demolition centres	Febelauto		years		15	14	15	15	15	16	16	16		22
valorization of EoL cars in Belgium: reuse	Febelauto		mass percentage		14	13	15	16	18	13	24	24		23
valorization of EoL cars in Belgium: recycling	Febelauto		mass percentage		74	76	73	73	73	79	69	70		23
valorization of EoL cars in Belgium: energetic valorization	Febelauto		mass percentage		3	4	6	5	6	4	4	4		23
valorization of EoL cars in Belgium: landfilling	Febelauto		mass percentage		9	7	6	6	3	4	3	3		23

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