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Impact of Circular Economy on achieving the climate targets: case mobility

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Impact of Circular Economy on achieving the climate targets: case mobility

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Summary

This study starts from the draft version of the **Flemish Climate Policy plan** and assesses the climate impact reduction of specific measures and strategies, with the objective to illustrate the added value of circular economy, which is from nature focusing on reducing the material footprint. The study looks at the climate impact from a consumption or footprint perspective, thus starting from Flemish consumption and including the value chain taking place in Flanders as well as outside Flanders. Territorial GHG-emissions are included separately to distinct between the effect on a global scale and on a Flemish scale. The mobility sector has been selected as a study case. The study focusses on passenger transport by car only.

The Flemish Climate policy plan starts from the objective of reducing the GHG emissions in Flanders with 35% by 2030 relative to 2005, following the Belgian target set by the EU. The plan identifies efforts for different sectors and sets sector-specific (sub)targets if necessary. Starting from the prognoses and targets defined in the Flemish policy plan 2021-2030, in this study three future scenarios are defined for the mobility sector for which the effect on GHG-emissions is assessed. GHG-emissions are calculated from a territorial and footprint perspective.

This study focusses on passenger transport by car only, this is reflected as well in the **scenarios**. The specific reduction target for passenger transport in the Flemish Climate Policy plan has been set at 51%. Each scenario focusses on a specific strategy (linked to specific parameters), e.g. electrification of the car park is only focussed on in the Technofix scenario, not in the CCS and LCS scenario. This allows to better assess the individual effect of a specific change/strategy and to create a better insight in the efforts required to reach a specific target or implement a specific strategy.
In total four scenarios are defined:

1. *Linear BAU scenario*
   This scenario serves as a reference and is comparable to the BAU-scenario defined in the Flemish climate policy plan.
2. *Technofix scenario (TEC) –100% new EV in 2030*
   This scenario assumes that by 2030 only electric vehicles are sold. The linear increase starts in 2020 and in 2030 100% of the new vehicles sold are battery electric vehicles.
3. *Linear climate scenario (LCS) – Drastically reduce demand for car transport to reach climate target in 2030*
   This scenario assumes that the climate goal for passenger road transport is reached by 2030 (-51% of territorial GHG-emissions compared to the 2015-value). This is realized by driving much less vehicle kilometres and by using more energy efficient vehicles.
4. *Circular climate scenario (CCS) – Drastically increase occupancy rate by implementing circular strategies (sharing, pooling, …) to reach climate target in 2030*
   This scenario assumes as well that the climate goal for passenger road transport is reached by 2030 (-51%). Additional circular economy strategies (car sharing, ride sharing, etc.) are implemented to reduce the effort requested from consumers, although a significant change in behaviour remains necessary.

The parameters defined in each scenario are summarized in the following table.

	Linear BAU scenario	*Technofix scenario*	*Linear climate scenario*	*Circular climate scenario*
Total car park total size (number of cars)	2020, 2025 and 2030 from data source; assumption of a linear trend in the periods 2021-2024 and 2026-2029		***calculated: total number of vehicle kilometres divided by the average number of vehicle kilometres per car per year***	
Total car park fuel technology (in percentages (share))	calculated based on distribution in year x-1, the new register cars in year x and the deregistered cars in year x			
Total car park GHG-emissions (in gram CO_2-eq. per kilometre)[1]	calculated based on values in year x-1, the new register cars in year x and the deregistered cars in year x			
newly registered cars total size (number of cars)	trend 2012-2017 is extrapolated		***calculated: the average ratio in the period 2015-2019 between the number of new vehicles and the total size of the car park is used to estimate the number of new vehicles in the period 2020-2030***	
newly registered cars fuel technology (in percentages)	2020, 2025 and 2030 from data source; assumption of a linear trend in the periods 2021-2024 and 2026-2029	***in 2030 the share battery electric vehicles in new vehicles is 100%; in the period 2020-2029 a linear increase between the 2019-value and 100% in 2030 is assumed; the other fuel technologies are gradually phased out***	2020, 2025 and 2030 from data source; assumption of a linear trend in the periods 2021-2024 and 2026-2029	
newly registered cars GHG-emissions (in gram CO_2-eq. per kilometre)	2020, 2025 and 2030 from data source; assumption of a linear trend in the periods 2021-2024 and 2026-2029		***emission factors are 10% lower compared to the BAU-scenario***	
deregistered cars total size (number of cars)	calculated based on the car fleet of the year x-1 plus the number of newly registered cars in year x minus the size of the car fleet in year x			
deregistered cars fuel technology (in percentages)	years 2009-2016: calculated based on the car fleet of the year x-1 plus the number of newly registered cars in year x minus the size of the car fleet in year x. 2017 onwards: the fuel type distribution of deregistered cars in year x is equal to the number of deregistered cars multiplied by the share of the fuel type distribution in the previous year.			
number of vehicle kilometres (in kilometres)	trend 2013-2016 is extrapolated		***2030: the number of vehicle kilometres linear declines to a certain value in 2030 to achieve the climate goal for passenger road transport emissions of -51% (compared to 2005); 2020-2029: a linear decrease is assumed between the 2019 and the 2030 value***	

[1] GHG-emissions is estimated as the total CO_2-equivalent (kg) including emissions from biofuels.

	Linear BAU scenario	*Technofix scenario*	*Linear climate scenario*	*Circular climate scenario*
number of person kilometres (in kilometres per person)	2020, 2025 and 2030 from data source; assumption of a linear trend in the periods 2021-2024 and 2026-2029		***calculated: number of vehicle kilometres multiplied by the occupancy rate***	***kept equal to the values in the BAU-scenario***
occupancy rate (in person kilometres per vehicle kilometres)	calculated: number of person kilometres divided by the number of vehicle kilometres		***kept equal to the values in the BAU-scenario***	**calculated: number of person kilometres divided by the number of vehicle kilometres**
number of vehicle kilometres per car (in kilometres per car)	calculated: number of vehicle kilometres divided by the total size of the car fleet		***kept equal to the values in the BAU-scenario***	***doubles in 2030 compared to the BAU-scenario; 2020-2029: a linear increase is assumed between the 2019 and the 2030 value***

Text in bold and italic is different compared to BAU-scenario

The following figures show the results of the model calculations for the four scenarios. Figures 0.1 and 0.2 show the trends in GHG-emissions for the consumption resp. territorial perspective. It is important to focus only on the general trends that are induced by the scenarios and not to focus on the details of the actual values.

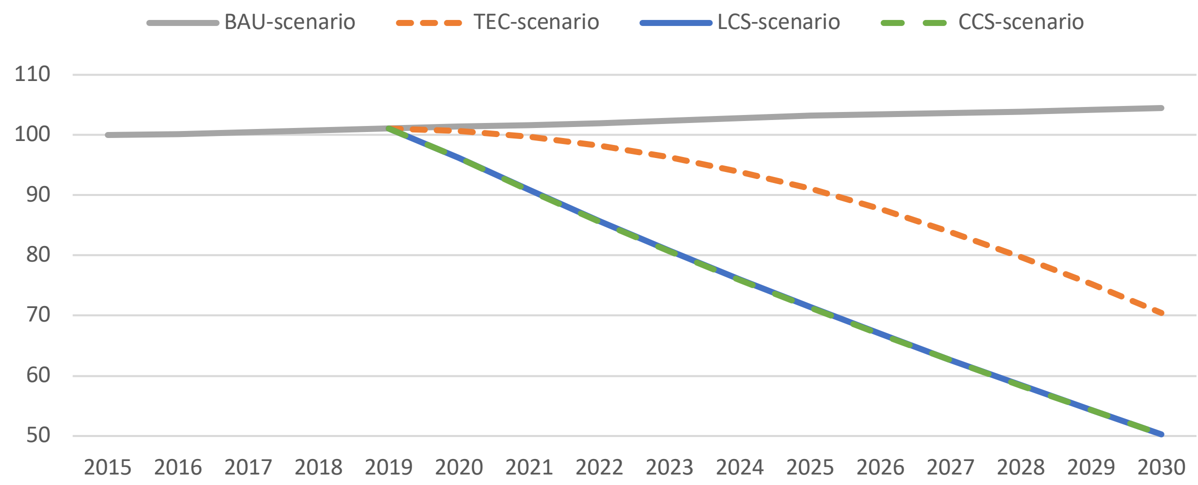


*Figure 0.1: Territorial GHG-emissions (only emissions in Flanders) of mobility in four scenarios (indexed values; 2015=100) [**territorial perspective**].*

While the **territorial GHG-emissions** according to the BAU-scenario increase in Flanders towards 2030, the other scenarios show a declining trend of GHG-emissions in a territorial perspective. This is expected as the TEC-, LCS- and CCS-scenario reduce primarily the in-use emissions, which occur in Flanders. When only a change in technology is introduced (TEC-scenario), territorial GHG-emissions will decrease, however not enough to reach the climate target as defined in the Flemish climate policy plan[2]. To reach the target, the renewal of the car park needs to be 100% electric from 2020 onwards. The territorial GHG-emissions according to the LCS- and CCS-scenario show that also a shift in our consumption behaviour is required to reach the climate targets. Either the demand for passenger transport by car needs to be reduced significantly (LCS), or the demand needs to be fulfilled in a different, more efficient way (CCS).

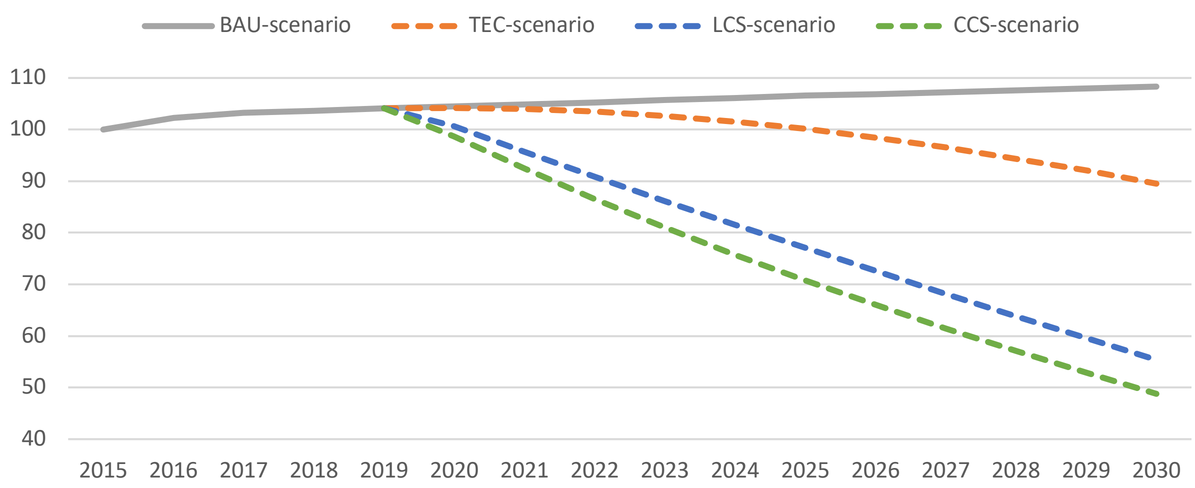


*Figure 0.2: Footprint GHG-emissions (global emissions) of mobility in four scenarios (indexed values; 2015=100) [**consumption perspective**].*

In a **consumption/footprint perspective** the same overall trend is visible: according to the BAU-scenario footprint GHG-emissions keep increasing, the other scenarios follow a decreasing trend. The TEC-scenario has more effect on the Flemish GHG-emissions (-30%, see Figure 21) than on the footprint GHG-emissions induced by Flemish demand for passenger transport by car (-10%, see Figure 20). The effect of the CCS-scenario on the GHG-emissions outside Flanders is higher than that of the LCS-scenario, due to the lower need for new vehicles in the CCS-scenario which are mostly produced outside Flanders.

When summarizing the **conclusions** that follow from this assessment, it is important to note that the assessment in this study and the defined scenarios don't predict the actual GHG-emissions until 2030, but merely show the potential of specific changes and the efforts required to reach the targets with regard to climate change impact of passenger transport by car. The assessment gives insight in the challenges and the feasibility of rather extreme scenarios and in the value of circular economy to fulfil our need for mobility in a more climate friendly way. The *TEC-scenario* clearly shows that electrification only is not sufficient to reach the climate target set in the Flemish climate policy plan. A reduction of the territorial GHG-emissions by 30% is reached instead of 51%. GHG-emission reduction occurs only during the use phase (in Flanders), GHG-emissions during production of cars increase because the GHG-impact for production of electric cars is higher than for traditional cars. The footprint GHG-emissions are reduced by only 10%. An additional reduction is possible by a transition of the electricity production mix to more renewable sources.

[2] These results are based on the assumption that the electricity production mix is constant over the period 2015-2030, and based on the 2015 electricity production mix in Belgium.

More 'extreme' measures are required to reach the climate target, as is illustrated by the *LCS-scenario*. This scenario assumes a very strong decrease of the amount of person-kilometers of 51% compared to 2015, requiring large efforts from consumers. Overall GHG-emissions are reduced with 45% (footprint perspective). GHG-emissions are reduced in all life cycle phases.
The *CCS-scenario* assumes circular economy strategies to facilitate and fulfil our mobility needs in a more comfortable way requiring less extreme efforts from consumers. The scenario has been developed to allow a reduction of territorial GHG-emissions of 51% compared to 2015. In a mobility context, carsharing and ridesharing are concrete examples of circular economy that may lead to this change[3]. The additional benefit of circular economy becomes clear when we consider the footprint GHG-emissions. Overall GHG-emission are reduced with 51%. There is an additional reduction of GHG-emissions for production of cars due to the lower number of cars required. Thus, circular economy can take care of an additional reduction without imposing too extreme constraints to consumers. Not captured by the scenarios or the model is the potential additional reduction of GHG-emissions caused by the fact that collaborative systems can better align with consumer needs in terms of e.g. size of cars. They can provide a mix of cars that fit different consumer needs, e.g. small cars that are more energy efficient and less climate intensive to produce can be used for 1 or 2 persons trips (so use of oversized cars is prevented).

The **footprint perspective** adds valuable insights to the trend of the territorial emissions. It allows to check for possible trade-offs between changes occurring in Flanders and the indirect effects of these changes/measures outside of Flanders. For example, the *TEC-scenario* reduces territorial emissions with 30% but causes an increase of more than 20% of GHG-emissions outside of Flanders for the production of the electric vehicles. The *LCS- and CCS-scenario* cause a 51% reduction of GHG-emissions in Flanders, however the reduction outside Flanders is higher in the CCS-scenario (>51%) than in the LCS-scenario (35%). In both scenarios less new cars need to be produced (mainly situated outside Flanders), but this reduction is more distinct in the CCS-scenario.

The scenarios require **efforts from different actors**. The *TEC-scenario* requires investments in infrastructure that support and facilitate the use of electric vehicles, e.g. charging stations, dedicated parking space, as well as infrastructure for recycling of batteries and electromotors. An important consequence of the electrification of the car park is the significant increase of the electricity demand (with ca. 3.4TWh in case of 36% electric vehicles in 2030 or even ca. 9.5TWh in case of 100% electric vehicles in 2030; compared to a net electricity production of 80TWh in 2017). Thus, investments to increase the electricity production infrastructure in Belgium/Flanders are required, with a focus on electricity production from renewable sources. The *LCS-scenario* requires high efforts from consumers, as much less mobility by car is allowed and more efficient cars are necessary. Consumers need to rely on other alternatives for their mobility (bike, on foot, public transport) which requires a huge behavioral change of consumers and thus needs to be facilitated as much as possible. Spatial planning is necessary to reduce the need for mobility and to invest in better public transportation and pedestrian/bike infrastructure. The *CCS-scenario* also requires high efforts from consumers as the demand for passenger transport by car needs to be fulfilled much more efficiently, which requires new systems like car sharing, carpooling systems to be much more widely in place and accepted.

[3] Other CE strategies can be reuse of car components, dedicated recycling of EV batteries and engines and the alignment between the needs and the means for mobility (e.g. align the size of a car to the need).

Also, public transportation is important in this scenario, so pedestrian and bike infrastructure is important and public transportation should be better aligned with car sharing systems.

The GHG-emissions related to the **EoL treatment of cars**[4] are not included in this assessment, although it is clear that the different scenarios have a different effect on EoL phase. In the *TEC-scenario* recycling of electromotors and batteries is an important issue, as this might require changes to the current recycling system. In the *LCS- and CCS-scenario* the number of new cars decreases, as does the number of cars in the car park. This might influence in the longer term the recycling sector, as less EoL vehicles will become available. Another issue is that cars are not at the end of their technical life span (number of vehicle kilometers) when they are 'disposed of' in Flanders. A lot of these cars are nowadays exported for 2nd life. In the CCS-scenario the cars are more efficiently used, and they will have reached their technical life span once disposed, thus less cars will be exported for 2nd life.

Ideally the assessment would not only include GHG-emissions but would focus as well on the **material impact** of these scenarios. It is clear that the scenarios all have an impact on the material footprint as well, although the impact is different.

[4] see also: https://www.eea.europa.eu/publications/electric-vehicles-from-life-cycle

Samenvatting

Deze studie vertrekt van de ontwerpversie van het **Vlaams Klimaatbeleidsplan** en onderzoekt de vermindering van klimaatimpact van specifieke maatregelen en strategieën, met als doel om de toegevoegde waarde van de circulaire economie te illustreren, die zich toespitst op het verminderen van de materialenvoetafdruk. De studie kijkt naar klimaatimpact vanuit een consumptie- of voetafdrukperspectief, en vertrekt dus van Vlaamse consumptie en omvat de waardeketen in en buiten Vlaanderen. Territoriale emissies van broeikasgassen (BKG) zijn apart vervat om het onderscheid te maken tussen het effect op globale en op Vlaamse schaal. De mobiliteitssector werd geselecteerd als case study. De studie richt zich enkel op personenvervoer met de wagen.

Het Vlaams Klimaatbeleidsplan vertrekt van de doelstelling om de uitstoot van broeikasgassen in Vlaanderen te verminderen met 35% tegen 2030 met 2005 als referentiejaar, en volgt hierin de Belgische doelstelling vanuit de EU. Het plan identificeert de inspanningen voor verschillende sectoren en stelt sectorspecifieke (sub)doelstellingen waar nodig. Uitgaande van de prognoses en doelstellingen gedefinieerd in het Vlaams Klimaatsplan 2021-2030 werden in deze studie drie toekomstscenario's gedefinieerd voor de mobiliteitssector waarvoor het effect op BKG-emissies bestudeerd is. Deze emissies zijn berekend vanuit een territoriaal- en een voetafdrukperspectief.

De studie focust enkel op personenvervoer met de wagen, wat ook weergeven is in de **scenario's**. De specifieke reductiedoelstelling voor personenvervoer in het Vlaams Klimaatbeleidsplan is gezet op 51%. Elk scenario spitst zich toe op een specifieke strategie (gelinkt aan specifieke parameters), bv. elektrificatie van het voertuigpark wordt enkel gericht bekeken in het technofix scenario, niet in de CKS- en LKS-scenario's. Dit laat toe om beter de individuele effecten van een specifieke verandering/strategie te zien en om beter inzicht te bieden in de vereiste inspanningen om een bepaalde doestelling te bereiken of een specifieke strategie te implementeren.
In totaal zijn vier scenario's gedefinieerd:

1. *Lineair Business-as-usial (BAU) scenario*
   Dit scenario dient als referentie en is vergelijkbaar met het BAU-scenario zoals gedefinieerd in het Vlaams Klimaatbeleidsplan
2. *Technofix scenario (TEC) – 100% nieuwe EV's in 2030*
   Dit scenario veronderstelt dat er tegen 2030 enkel elektrische voertuigen verkocht worden. De lineaire toename begint in 2020 en in 2030 zijn 100% van de nieuw verkochte voertuigen elektrische voertuigen met batterij.
3. *Lineair klimaatscenario (LKS) – Drastisch verminderde vraag naar voertuigvervoer om de klimaatdoelstelling in 2030 te halen*
   Dit scenario neemt aan dat de klimaatdoelstelling voor personenvervoer over de weg bereikt wordt tegen 2030 (-51% territoriale BKG-emissies vergeleken met 2015). Dit wordt gerealiseerd door veel minder voertuigkilometers af te leggen en door voertuigen met een hogere energie-efficiëntie te gebruiken.
4. *Circulair klimaatscenario (CKS) – Drastisch toegenomen bezettingsgraad door het implementeren van circulaire strategieën (autodelen, ritdelen) om de klimaatdoelstelling in 2030 te bereiken*

Dit scenario veronderstelt eveneens dat de klimaatdoelstelling voor personenvervoer over de weg bereikt wordt tegen 2030 (-51%). Bijkomende circulaire economie strategieën (autodelen, ritdelen enz.) worden geïmplementeerd om de inspanningen die aan de consumenten gevraagd worden te verminderen, ook al zal er een belangrijke verandering in gedrag nodig blijven.

De parameters zoals gedefinieerd in elk scenario zijn samengevat in onderstaande tabel.

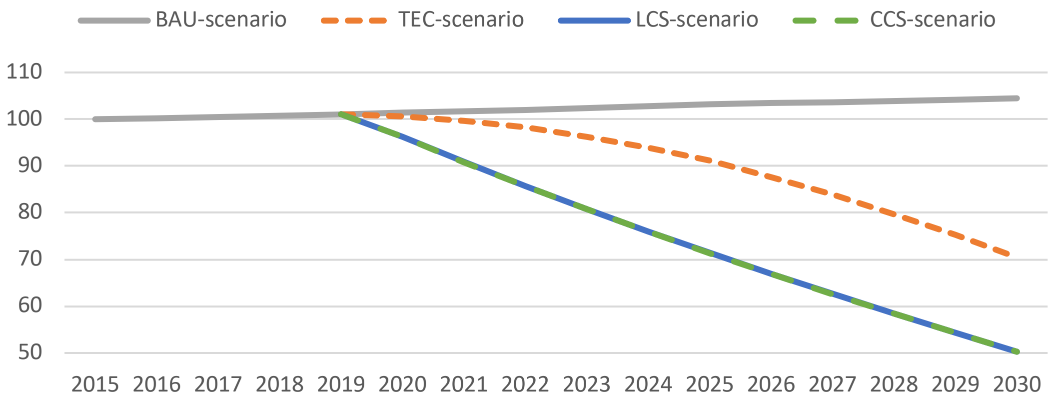
	Lineair BAU scenario	*Technofix scenario*	*Lineair klimaat-scenario*	*Circulair klimaat-scenario*
Totaal wagenpark Totale grootte (aantal voertuigen)	2020, 2025 en 2030 vanuit databronnen; lineaire trend verondersteld in de periodes 2021-2024 en 2026-2029		***berekend: totaal aantal voertuigkilometers gedeeld door het gemiddelde aantal voertuigkilometers per voertuig per jaar***	
Totaal wagenpark brandstoftechnologie (in percentages (aandeel))	berekend op basis van de verdeling in het jaar x-1, de nieuw ingeschreven voertuigen in jaar x en de uitgeschreven voertuigen in jaar x			
Totaal wagenpark BKG-emissions (in gram CO_2-eq. per kilometer)[5]	berekend op basis van de verdeling in het jaar x-1, de nieuw ingeschreven voertuigen in jaar x en de uitgeschreven voertuigen in jaar x			
Nieuw ingeschreven voertuigen Totale grootte (aantal voertuigen)	extrapolatie van trend 2012-2017		***berekend: de gemiddelde verhouding in de periode 2015-2019 tussen het aantal nieuwe voertuigen en de totale grootte van het wagenpark werd gebruikt om het aantal nieuwe voertuigen in de periode 2020-2030 in te schatten***	
Nieuw ingeschreven voertuigen brandstoftechnologie (in percentages)	2020, 2025 en 2030 vanuit databronnen; lineaire trend verondersteld in de periodes 2021-2024 en 2026-2029	***in 2030 is het aandeel elektrische voertuigen met batterij 100%; in de periode 2020-2029 is een lineaire toename tussen de waarde voor 2019 en 100% in 2030 verondersteld; de andere brandstoftechnologieën worden geleidelijk uitgefaseerd***	2020, 2025 en 2030 vanuit databronnen; lineaire trend verondersteld in de periodes 2021-2024 en 2026-2029	
Nieuw ingeschreven voertuigen BKG-emissies (in gram CO_2-eq. per kilometer)	2020, 2025 en 2030 vanuit databronnen; lineaire trend verondersteld in de periodes 2021-2024 en 2026-2029		***emissiefactoren zijn 10% lager vergeleken met het BAU-scenario***	
Uitgeschreven voertuigen Totale grootte (aantal voertuigen)	berekend op basis van de verdeling in het jaar x-1, de nieuw ingeschreven voertuigen in jaar x en de uitgeschreven voertuigen in jaar x			
Uitgeschreven voertuigen	jaren 2009-2016: berekend op basis van het voertuigenpark van jaar x-1 plus het aantal nieuw ingeschreven voertuigen in jaar x min de grootte van het voertuigenpark in jaar x.			

[5] BKG-emissies zijn geschat als het totaal CO_2-equivalent (kg) met inbegrip van emissies van biobrandstoffen.

<table>
<tr><th></th><th>Lineair BAU scenario</th><th>Technofix scenario</th><th>Lineair klimaat-scenario</th><th>Circulair klimaat-scenario</th></tr>
<tr><td>brandstoftechnologie (in percentages)</td><td colspan="4">vanaf 2017: de verdeling van brandstoftypes van uitgeschreven voertuigen in jaar x is gelijk aan het aantal uitgeschreven voertuigen vermenigvuldigd met het aandeel van de verdeling van brandstoftypes in het voorgaande jaar</td></tr>
<tr><td>Aantal voertuigkilometers (in kilometers)</td><td colspan="2">trend van 2013-2016 geëxtrapoleerd</td><td colspan="2">2030: het aantal voertuigkilometers neemt lineair af tot een bepaalde waarde in 2030 zodat de klimaatdoelstelling voor personenvervoer over de weg van -51% (vergeleken met 2005) bereikt wordt;
2020-2029: een lineaire afname wordt verondersteld tussen de waardes voor 2019 en voor 2030</td></tr>
<tr><td>Aantal voertuigkilometers (in kilometers per persoon)</td><td colspan="2">2020, 2025 en 2030 vanuit databronnen; lineaire trend verondersteld in de periodes 2021-2024 en 2026-2029</td><td>berekend: aantal voertuigkilometers vermenigvuldigd met de bezettingsgraad</td><td>gelijk gehouden met de waarden in het BAU-scenario</td></tr>
<tr><td>Bezettingsgraad (in personenkilometers per voertuigkilometers)</td><td colspan="2">berekend: aantal personenkilometers gedeeld door aantal voertuigkilometers</td><td>gelijk gehouden met de waarden in het BAU-scenario</td><td>berekend: aantal personen-kilometers gedeeld door het aantal voertuig-kilometers</td></tr>
<tr><td>Aantal voertuigkilometers per voertuig (in kilometers per voertuig)</td><td colspan="2">berekend: aantal voertuigkilometers gedeeld door totale grootte van het wagenpark</td><td>gelijk gehouden met de waarden in het BAU-scenario</td><td>verdubbeld in 2030 vergeleken met het BAU-scenario; 2020-2029: een lineaire toename verondersteld tussen de waarden voor 2019 en 2030</td></tr>
</table>

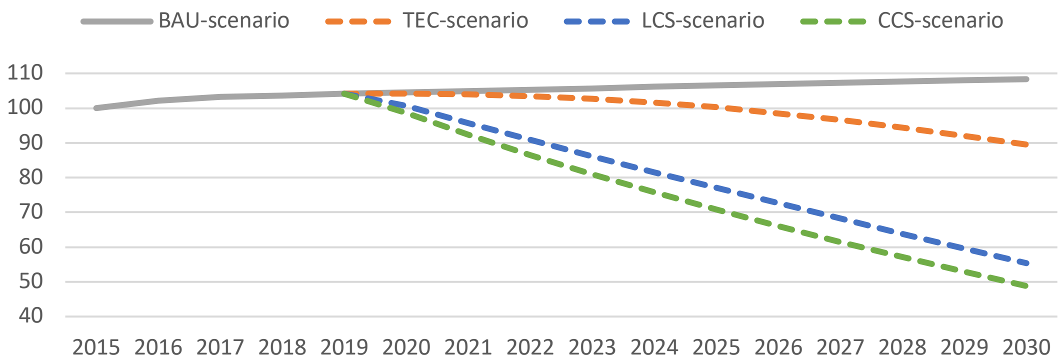
Tekst in vet en cursief is verschillend vergeleken met BAU-scenario

De volgende figuren tonen de resultaten van de modelberekeningen voor de vier scenario's. Figuren 0.1 en 0.2 tonen de trends in BKG-emissies resp. voor het consumptie en het territoriaal perspectief. Het is belangrijk om enkel te focussen op de algemene trends geïnduceerd door de scenario's en niet op de details van de actuele getallen.



*Figuur 0.1: Territoriale BKG-emissies (enkel emissies in Vlaanderen) van mobiliteit in vier scenario's (geïndexeerde waardes; 2015=100) [**territoriaal perspectief**].*

Terwijl de **territoriale BKG-emissies** volgens het BAU-scenario toenemen in Vlaanderen tegen 2030, tonen de andere scenario's een dalende trend van BKG-emissies in een territoriaal perspectief. Dit is zoals verwacht, aangezien de TEC-, LKS- en CKS-scenario's voornamelijk de gebruiksemissies doen afnemen, die plaatsvinden binnen Vlaanderen. Wanneer enkel een verandering in technologie ingevoerd wordt (TEC-scenario), zullen territoriale BKG-emissies afnemen, zij het echter niet voldoende om de klimaatdoelstelling te halen zoals gedefinieerd in het Vlaams Klimaatbeleidsplan[6]. Om de doelstelling te halen moet de vernieuwing van het wagenpark 100% elektrisch zijn vanaf 2020. De territoriale BKG-emissies overeenstemmend met het LKS- en het CKS-scenario tonen ook dat een verschuiving in ons consumptiegedrag vereist is om de klimaatdoelstelling te halen. Ofwel moet de vraag naar personenvervoer met de wagen significant afnemen (LKS), ofwel moet de vraag op een andere, meer efficiënte manier ingevuld worden (CKS).



*Figuur 0.2: Voetafdruk-BKG-emissies (globale emissies) van mobiliteit in vier scenario's (geïndexeerde waardes; 2015=100) [**consumptieperspectief**].*

In een **consumptie/voetafdrukperspectief** is algeeen dezelfde trend zichtbaar: volgens het BAU-scenario blijven de voetafdruk-BKG-emissies stijgen, de andere twee scenario's volgen een afnemende trend. Het TEC-scenario heeft meer effect op de Vlaamse BKG-emissies (-30%, zie Figuur 21) dan op de voetafdruk-BKG-emissies als gevolg van de Vlaamse vraag voor personenvervoer met de wagen (-10%, zie Figuur 20). Het effect van het LKS-scenario op de

[6] Deze resultaten zijn gebaseerd op de veronderstelling dat de elektriciteitsproductiemix constant is over de periode 2015-2030, en op de elektriciteitsproductiemix in 2015 in België.

BKG-emissies buiten Vlaanderen is hoger dan dat van het LKS-scenario, door de lagere behoefte aan nieuwe voertuigen in het CKS-scenario die voor het grootste gedeelte buiten Vlaanderen geproduceerd worden.

Wanneer we de **conclusies** die volgen uit deze studie samenvatten, is het belangrijk te vermelden dat de gedefinieerde scenario's niet de actuele BKG-emissies tegen 2030 voorspellen, maar louter het potentieel van specifieke veranderingen en de vereiste inspanningen om de doelstellingen met betrekking tot klimaatverandering in personenvervoer met de wagen. De studie levert inzichten in de uitdagingen en de haalbaarheden van veeleer extreme scenario's en in de waarde van de circulaire economie om onze mobiliteitsbehoefte in te vullen op een meer klimaatvriendelijke wijze. Het *TEC-scenario* toont duidelijk dat enkel elektrificatie niet voldoende is om de klimaatdoelstelling zoals gesteld in het Vlaams Klimaatbeleidsplan te halen. Een afname van de territoriale BKG-emissie van 30% wordt bereikt in plaats van 51%. Vermindering van BKG-emissies vindt enkel plaats tijdens de gebruiksfase (in Vlaanderen), BKG-emissies bij de productie van voertuigen nemen toe omdat de BKG-impact voor de productie van elektrische voertuigen hoger ligt dan voor conventionele voertuigen. De voetafdruk-BKG-emissies nemen slechts 10% af. Een bijkomende afname is mogelijk via een transitie van de elektriciteitsproductiemix naar meer hernieuwbare bronnen.

Zoals geïllustreerd door het *LKS-scenario*, zijn meer 'extreme' maatregelen nodig om de klimaatdoelstelling te halen. Dit scenario verondersteld een zeer sterke afname in de hoeveelheid personenkilometers van 51% in vergelijking met 2015, wat zeer grote inspanningen vergt van consumenten. Globale BKG-emissies nemen af met 45% (voetafdrukperspectief), BKG-emissies nemen af in alle fases van de levenscyclus.

Het *CKS-scenario* gaat uit van strategieën van de circulaire economie om onze mobiliteitsbehoefte te faciliteren en te vervullen op een meer comfortabele manier die minder extreme inspanningen vergt van consumenten. Het scenario is ontwikkeld om een reductie in territoriale BKG-emissies van 51% te halen vergeleken met 2015. In een mobiliteitscontext zijn autodelen en ritdelen concrete voorbeelden van circulaire economie die tot deze veranderingen kunnen leide[7]. Het bijkomende voordeel van circulaire economie wordt duidelijk wanneer we de voetafdruk-BKG-emissies bekijken. Globale BKG-emissies dalen met 51%. Er is een bijkomende afname van BKG-emissies voor de productie van voertuigen omdat er minder voertuigen nodig zijn. Zodus zorgt de circulaire economie voor een bijkomende afnamen zonder te extreme beperkingen op te leggen aan consumenten. Niet vervat in de scenario's of het model is de potentieel bijkomende afname van BKG-emissies veroorzaakt door het feit dat collaboratieve systemen beter afgestemd kunnen worden op de noden van consumenten, bv. de grootte van voertuigen. Dergelijke systemen kunnen een mix van voertuigen aanbieden aangepast aan verschillende noden, bv. kleinere, energie-efficiënte voertuigen die klimaatvriendelijker geproduceerd kunnen worden voor gebruik voor 1 of 2 personen (zodus wordt het gebruik van te grote voertuigen voorkomen).

Het **voetafdrukperspectief** voegt waardevolle inzichten toe aan de trend van territoriale emissies. Dit laat toe om mogelijke trade-offs na te gaan tussen veranderingen die optreden in

[7] Andere CE-strategieën zijn bijvoorbeeld het hergebruiken van onderdelen, recyclage van batterijen en motoren van elektrische voertuigen en het afstemmen van transportmiddelen met de behoeftes (bv. het afstemmen van de grootte van een voertuig op de noden).

Vlaanderen en de indirecte effecten van deze veranderingen/maatregelen buiten Vlaanderen. Bijvoorbeeld, het TEC-scenario vermindert territoriale emissies met 30% maar veroorzaakt een toename van meer dan 20% in BKG-emissies buiten Vlaanderen voor de productie van elektrische voertuigen. De LKS- en CKS-scenario's veroorzaken een vermindering van 51% van BKG-emissies in Vlaanderen, echter is de afname buiten Vlaanderen hoger in het CKS-scenario (>51%) dan in het LKS-scenario (35%). In beide scenario's moeten er minder nieuwe voertuigen geproduceerd worden (hoofdzakelijk buiten Vlaanderen), maar deze afname is meer uitgesproken in het CKS-scenario.

De scenario's vereisen **inspanningen van verschillende actoren**. Het TEC-scenario vereist investeringen in infrastructuur die het gebruik van elektrische voertuigen ondersteunen en faciliteren, bv. laadstations, speciaal voorziene parkeerrruimte, evenals infrastructuur voor de recyclage van batterijen en elektromotoren. Een belangrijk gevolg van de elektrificatie van het voertuigenpark is de significante toename van de elektriciteitsvraag (met ong. 3.4 TWh in geval van 36% elektrische voertuigen in 2030 of zelfs ca. 9.5 TWh in geval van 100% elektrische voertuigen in 2030; te vergelijken met een netto elektriciteitsproductie van 80 TWh in 2017). Zodus zijn investeringen om de productie-infrastructuur van elektriciteit vereist in België/Vlaanderen, met een focus op productie vanuit hernieuwbare bronnen. Het LKS-scenario vereist grote inspanningen van consumenten, omdat veel minder mobiliteit met de wagen toegelaten wordt en meer efficiënte voertuigen nodig zijn. Consumenten zullen dan moeten steunen op andere alternatieven voor hun mobiliteit (fiets, te voet, openbaar vervoer), wat enorme gedragsveranderingen zal vergen van consumenten en dit moet dus zo veel als mogelijk gefaciliteerd worden. Ruimtelijke ordening is nodig om de mobiliteitsbehoefte te doen afnemen en te investeren in beter openbaar vervoer en infrastructuur voor voetgangers en fietsers. Het CKS-scenario vereist ook grote inspanningen van consumenten omdat de vraag naar personenvervoer met de wagen efficiënter moet ingevuld worden, wat nieuwe systemen zoals autodelen en ritdelen vereist die veel meer beschikbaar en aanvaard worden. Ook openbaar vervoer is belangrijk in dit scenario, en infrastructuur voor voetgangers en fietsers is belangrijk en openbaar vervoer moet beter afgestemd worden met systemen voor autodelen.

De BKG-emissies gerelateerd aan de **behandeling van voertuigen op het einde van hun levenscyclus** zitten niet in deze studie begrepen, ook al is het duidelijk dat de verschillende scenarios een verschillend effect hebben op deze fase. In het TEC-scenario is recyclage van elektromotoren en batterijen een belangrijk punt, omdat dit veranderingen kan vergen van de huidige recyclagesystemen. In het LKS- en CKS-systeem neemt de hoeveelheid nieuwe wagens af, evenals het aantal voertuigen in het wagenpark. Dit kan op langere termijn een invloed hebben op de recyclagesector, omdat minder afgedankte voertuigen ter beschikking zullen komen. Een ander punt is dat voertuigen niet noodzakelijk het einde van hun technische levenscyclus (aantal voertuigkilometers) bereiken in Vlaanderen wanneer ze uitgeschreven worden. Veel van deze voertuigen worden momenteel uitgevoerd voor een volgende gebruikscyclus. In het CKS-scenario worden de voertuigen meer efficiënt gebruikt, en ze zullen hun technische levensduur bereikt hebben op het moment van uitschrijving, dus zullen er minder wagens uitgevoerd worden voor een volgende gebruikscyclus.

Idealiter zou deze studie niet enkel de BKG-emissies behandelen maar ook de **materialenimpact** van deze scenario's. Het is duidelijk dat alle scenario's eveneens een impact hebben op de materialenvoetafdruk, maar die zal verschillen per scenario.

Table of Contents

Chapter 1: Introduction

International climate policy sets specific and clear targets to GHG-emissions: global GHG-emissions need to be reduced with 90% by 2050 compared to 1990. In a regional context, the Flemish Climate Policy Plan defines targets for the GHG-emissions that occur in Flanders[8] and starts from the objective of reducing the GHG emissions in Flanders with 35% by 2030 relative to 2005, following the Belgian target set by the EU. Although the plan focusses on the territorial emissions (in Flanders) it is stated that burden shifting should be avoided and footprint (consumption) indicators are preferably considered as well to identify potential risk of burden shifting. Indeed, it is known that an important share of the carbon footprint of Flanders is caused by GHG-emissions elsewhere. Emissions in Flanders and abroad are due to the extraction of materials, transportation and production, and use and end of life of all kinds of products. A detailed analysis of the carbon and material footprint of Flanders is already performed and reported[9], which illustrates the relation between both.

Circular Economy is in the Flemish Climate Policy Plan referred to as one of the transversal measures and it is explicitly stated that a transition towards a green and circular economy is necessary to reach the climate targets. This study intends to define different measures to reach the climate target and assesses the added value of circular economy, which is from nature focusing on reducing the material footprint, in this context. In consultation with the steering committee the mobility sector is selected as a study case.

The assessment in this study is based on a quantitative model that uses available data for the parameters that influence the GHG-emissions of mobility. To assess the climate impact reduction potential of circular economy strategies specific for mobility, we start from the as is situation in a reference year (2015) and assess the evolution of the GHG-emissions according to different scenario's. A BAU-scenario is defined to have a baseline to compare the other scenarios to. Each scenario focusses on a specific strategy and can be considered a rather 'extreme' scenario, allowing to specifically assess the individual effect of a specific change/strategy and to create a better insight in the efforts required to reach a specific target or implement a specific strategy. GHG-emissions are calculated both from a territorial and footprint perspective. The study only focusses on the effect on GHG-emissions and does not intend to look for policy instruments that can support these scenarios and measures nor to include financial effects like rebound in the assessment.

The study focusses on passenger transport by car only. The assessment starts from a footprint or consumption perspective and thus includes all stages in the life cycle of products related to mobility (e.g. production of cars, fuels, electricity, lubricants, …). The study excludes the treatment of end of life vehicles, thus doesn't take into account the effect on the end of life treatment and the second life vehicles. This is important to keep in mind, as the scenarios do have an effect on either the number of end of life vehicles or the end of life technology as other

[8] This is according to the international and European climate policy, which is based on reduction targets on a country (territorial)-level.

[9] "Koolstofvoetafdruk van de Vlaamse consumptie" (commissioned by VMM-MIRA, executed by VITO, finalized in 2017) and "Secundaire Materialen in de Input-Outputtabellen" (commissioned by OVAM, executed by VITO, finalized in 2018)

components and materials enter the recycling market (e.g. electric vehicles with electromotors and batteries).

In an introductory chapter 2 the report summarizes the targets, measures and scenarios included in the Flemish Climate Policy Plan for transport. In chapter 3 the current state of play is discussed, including results and conclusions from consumption-based assessments specific for transport and mobility. This chapter gives an overview of the relevant parameters and the available data. Chapter 4 reports the scenarios that are identified and discusses the trend in GHG-emissions according to these scenarios. Finally, in chapter 5 conclusions are listed that follow from the analysis performed in this study.

Chapter 2: Summary of Flemish climate policy targets 2021-2030

2.1 Introduction

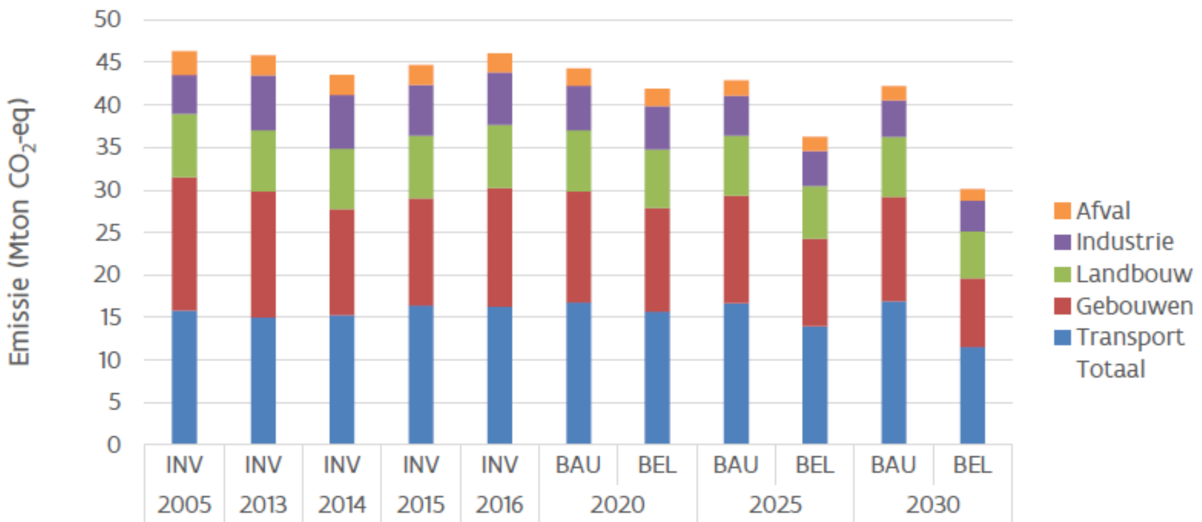
The Flemish Climate policy plan starts from the objective of reducing the GHG emissions in Flanders with 35% by 2030 relative to 2005, following the Belgian target set by the EU. The plan identifies efforts for different sectors and sets sector-specific (sub)targets if necessary. The plan includes measures as well that are necessary to reach the targets.
It is defined by the European Effort Sharing Regulation[10] (ESR) that GHG emissions should be reduced according to a linearly decreasing trend for the period 2021-2030, with the starting point in May 2019 (average of 2016-2018) and the end point in 2030 (set on -35% of non-Emission Trading System (ETS) emissions in 2005).

The Flemish Climate policy plan focusses on the non-ETS sectors - built environment, transport, agriculture, waste and some industry sectors – and focusses as such on the direct emissions of these sectors. However, care must be taken that reduction measures cause as little indirect emissions as possible in ETS-sectors or outside Flanders, e.g. by electrification of the vehicle fleet.
An additional point of attention is the fact that the 'accounting' method (as agreed on European level) might lead to a distorted image of the climate efforts of the respective sectors when they are looked at individually. This is particularly relevant for the agriculture and industry sector. As such it is important to look at the efforts in a larger context and to appreciate and stimulate cross-sectoral efforts. Moreover, the climate impact must be assessed from a life cycle perspective. Imported emissions related to products that are imported in Flanders for our Flemish consumption need to be considered as well.

2.2 General prognoses

In 2016 transport (35%) and buildings (30%) contributed most to the non-ETS GHG emissions in Flanders. Agriculture (16%), industry (13%) and waste (5%) were responsible for a smaller share. Based on the inventory of emissions between 2005-2016 and two scenarios (BAU and policy scenario) for 2016-2030, prognoses are made for GHG emissions related to the non-ETS sectors.

[10] https://ec.europa.eu/clima/policies/effort/proposal_en



	INV 2005	INV 2013	INV 2014	INV 2015	INV 2016	BAU 2020	BEL 2020	BAU 2025	BEL 2025	BAU 2030	BEL 2030
Afval	2,8	2,4	2,3	2,4	2,2	2,0	2,0	1,8	1,7	1,7	1,4
Industrie	4,5	6,5	6,3	6,0	6,2	5,2	5,1	4,7	4,1	4,3	3,6
Landbouw	7,5	7,2	7,1	7,3	7,4	7,3	6,9	7,0	6,2	7,1	5,5
Gebouwen	15,7	14,8	12,5	12,6	14,0	13,0	12,2	12,6	10,3	12,3	8,1
Transport	15,8	15,0	15,3	16,4	16,3	16,8	15,7	16,7	14,0	16,9	11,5
Totaal	46,3	45,8	43,5	44,7	46,1	43,6	41,9	42,2	36,3	41,5	30,1

Figure 1: Non-ETS GHG emissions in Flanders 2005-2030 (Mton CO2-eq) (Source: Vlaams Klimaatbeleidsplan 2021-2030).

Non-ETS GHG emissions in Flanders decreased from 46.3 million ton CO_2-eq. in 2005 until 46.1 million ton CO_2-eq. in 2016. According to a BAU-scenario a reduction of 10% will be realized in 2030 relative to 2005, according to a policy scenario (BEL) a reduction of 35% will be realized. Between 2005-2016 the most important reduction has been observed in the building sector (-11%) and the waste sector (-22%). The transport sector shows an increase of 3%, the industry sector of 36%. This plan foresees in a further reduction by 2030 in the building sector (-46%) and a switch to a reduction in the transport sector to -27% and in industry to -21%.

2.3 Sector Transport

2.3.1 Relevant parameters

Important **parameters** for defining the status (2005-2016) and the scenarios (until 2030) for the transport sector are listed in this paragraph.

A. Transport volumes and vehicle efficiency

- Number of vehicle kilometres (vkm):
  The source and methodology for defining the number of vehicle kilometres for road traffic was changed in 2013[11].
  Between 2005-2016:

[11] FOD Mobiliteit en Vervoer 2005-2012, Vlaams verkeerscentrum 2013-…

- vkm by passenger cars increased with 9%; and
- vkm by vans and trucks increased with 13% resp. 7%

- Energy efficiency of vehicles:
  Improved slightly between 2005-2016, but not sufficient to compensate the increase in volume (vkm).

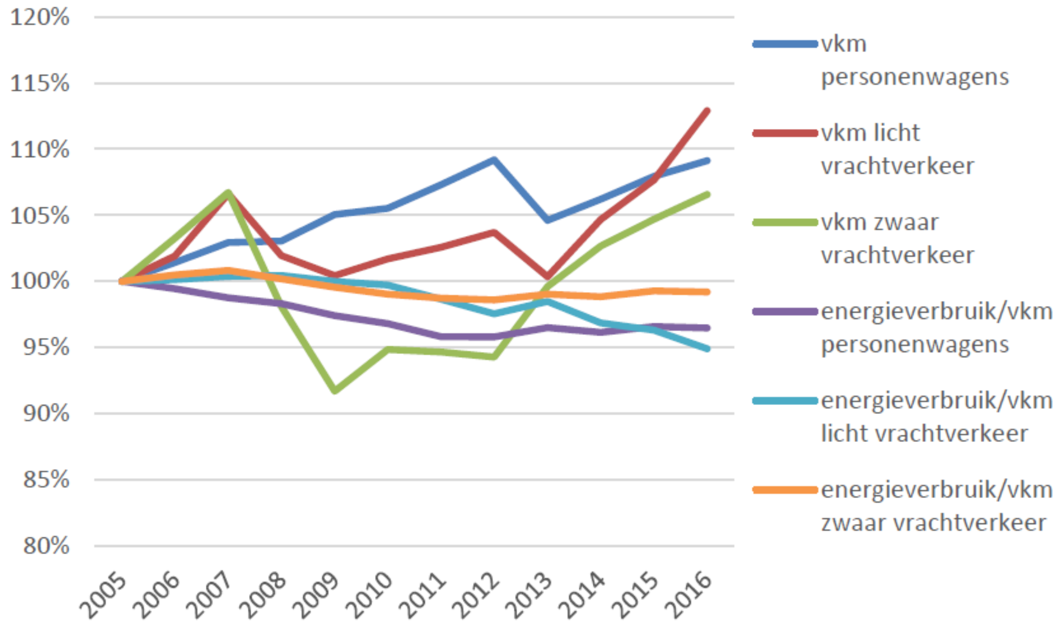


Figure 2: Volumes (vkm) and efficiency of road transport in Flanders (source: Vlaams Klimaatbeleidsplan 2021-2030[12]).

B. *Size and composition of the vehicle fleet*

- Share of fuel technology in new vehicles:
  Share of diesel cars in new cars (purchases) decreased to 51% in 2016.
  Data on the purchase of new cars in 2017[13]: 46% diesel, 48% gasoline, 5% alternative technology.
  Target: 7.5% battery-electric vehicles (new cars) by 2020
- Number of vehicles in fleet:
  The size of the Flemish passenger car fleet increased with 18% between 2005-2016.

[12] Source data: VMM, maart 2018
[13] Febiac (2017), data for Belgium.

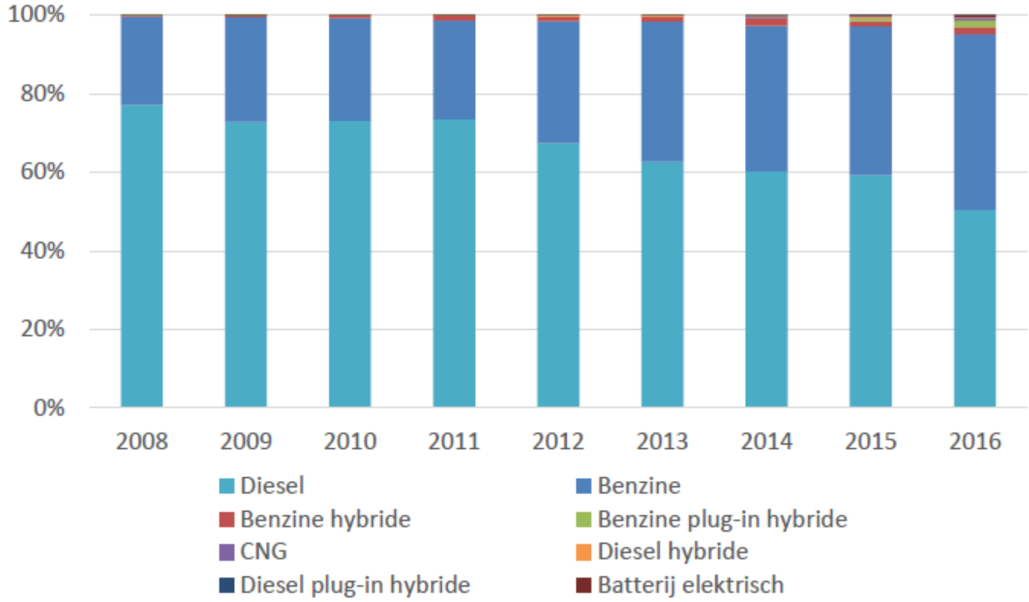


Figure 3: Share of fuel technology in new passenger cars (source: Vlaams Klimaatbeleidsplan 2021-2030[14]).

C. Modal share

The previous parameters focus on the (private) road transport, however the shift to other transport modes and public transport (bus, train, bike) is also an important parameter. Between 2005-2015 the share of cars/motorcycles decreased from 84% to 79%, however remains stable after 2015. For freight transport the road traffic has the largest share in terms of volumes, and this shows an increasing trend (75% in 2000 and 80% in 2015).

In 2016 the transport sector as a whole was responsible for 16,3 million-ton CO_2-eq., which corresponds to 35% of total Flemish non-ETS GHG-emissions. These include emissions of passenger and freight road traffic and emissions of transport by rail and ship and include bunkers. This number only considers the GHG-emissions related to the use of fossil fuels, and thus not the emissions related to electricity production (for electric trains, bikes and road vehicles) nor emissions related to biofuels (set at zero conform European and international rules). The GHG-emissions for the transport sector are mainly related to the **use of fossil fuels for passenger transport and freight transport by road, rail transport (diesel trains) and inland shipping**.

[14] Source data: Ecoscore reports

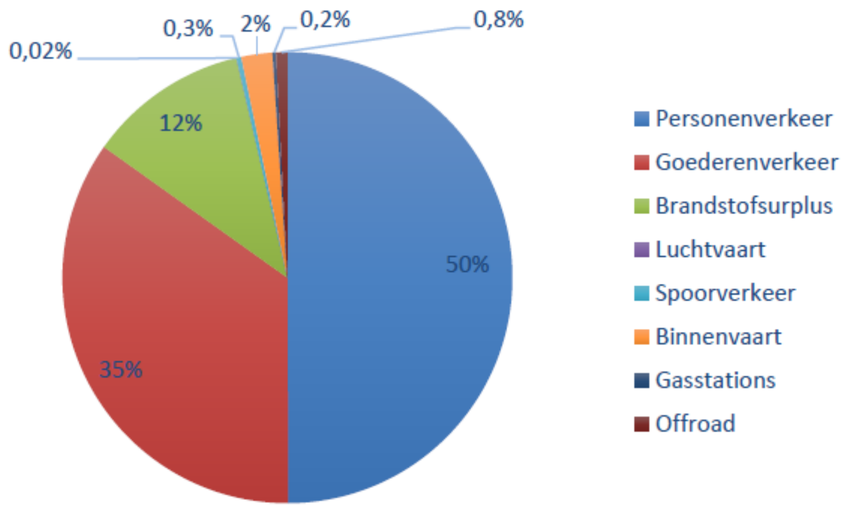


Figure 4: Share of Flemish non-ETS GHG-emissions of the transport sector[15] (source: Vlaams Klimaatbeleidsplan 2021-2030).

It is important to clearly define the scope of this study. In this context the above graph gives relevant information. Road transport (passenger + freight) is responsible for most of the GHG-emissions of the transport sector. The smaller contribution of aviation is due to the fact that only intra-European GHG-emissions are included (ETS).

2.3.2 Targets

By 2030 the **GHG-emissions of road transport** decrease with at least **27%** compared to 2005 (in absolute terms: max. 11.5 million-ton CO_2-eq. emissions by road transport in 2030).

Targets related to **spatial planning** are not further considered for our scenario's in this study.

Targets related to **mobility development**:

- *Vkm by road transport* decrease to max. 51.6 billion in 2030, which corresponds to a *reduction of 12% compared to 2015 for cars and vans*, and a limitation of the increase to max. 14% for trucks.
- Development of *multimodal transportation system*:
  - Commuting traffic: min. 40% share of sustainable modes (max. 60% car).
  - Strong urban areas (Antwerp, Gent, Vlaamse rand): 50% share of sustainable modes.
  - Freight transport:
    - shift of 6.3 billion ton-kilometre from road to alternative modes (water or rail);
    - share of rail and inland shipping: 30%; and
    - seaports: increase share of sustainable modes with 5-10% (compared to 2013).

[15] Fuel surplus: correction factor for fuel sales due to difference between emissions calculated with emission models and reported emissions based on federal fuel sale data

- Sustainable travel and transport behaviour: no relevant parameters/targets for this study.

Targets related to **low carbon and zero emission vehicles:**

- In 2030 are
  - all new passenger cars low carbon, and min. 50% even zero emission vehicles;
  - all public busses in urban areas low carbon, and in city centres zero emission;
    - From 2019 on De Lijn will only buy low carbon busses.
  - min. 5% of new heavy trucks is low carbon; and
  - min. 30% of new light trucks/vans are low carbon.

Targets related to **recycled fossil fuels and biofuels**: In 2030 14% addition of biofuels is targeted.

2.3.3 Policy measures

No quantitative information directly relevant for this study.

2.3.4 Prognoses

Evolution of road transport – **number of vkm**:

- BAU-scenario:
  - Development of mobility without additional policy
  - Increasing population
  - Increasing number of jobs

  Increase of vkm for passenger cars and vans with 1%, for heavy trucks with 19% (2030 compared to 2015).
- Policy scenario:
  - See before

  Reduction of vkm for passenger cars and vans with 12%, increase with 14% for heavy trucks.

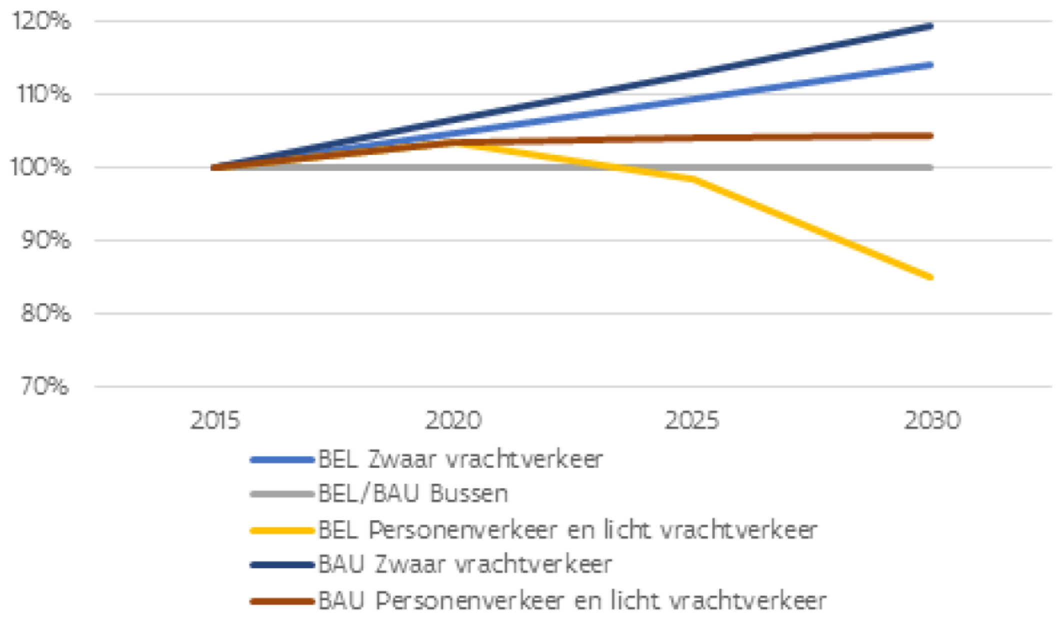


Figure 5: Evolution of vehicle kilometres per type of vehicle in 2015-2030 (source: Vlaams Klimaatbeleidsplan 2021-2030).

Evolution of road transport – **vehicle park/fleet**:

- BAU scenario:
  - Autonomous evolution of vehicle park starting from 2015
  - Old vehicles are replaced by new vehicles
  - New passenger cars: share of fuel technology types in 2016 is considered the same until 2030
  - New Public Transport busses: 2/3rd of new busses in 2016 is hybrid CS, by 2030 only low carbon new busses
  - Other vehicles: same fuel technology composition as in 2015.
- Policy scenario:
  - See figure below
  - Efficiency improvements:
    - For passenger cars: -10% energy use from construction year 2020 onwards
    - Heavy trucks: -5% energy use from construction year 2020 onwards
  - Addition of biofuels:
    - 2020-2024: 9% on average
    - 2025-2029: 12% on average
    - 2030: 14%

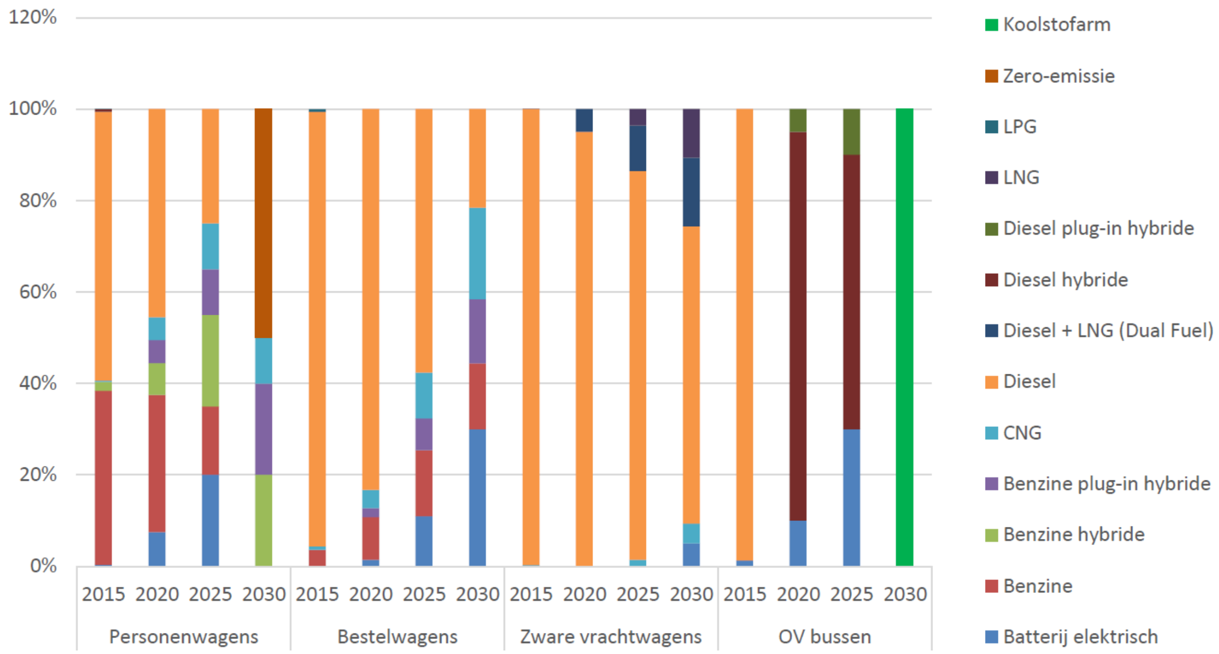


Figure 6: Share of fuel technology for new vehicles in 2015-2030 (source: Vlaams Klimaatbeleidsplan 2021-2030).

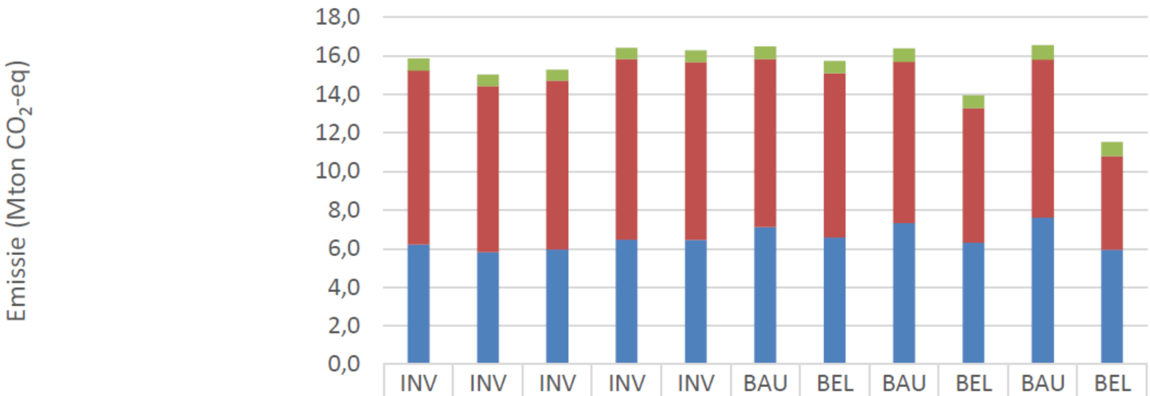
For off road activities and other transport modes: only BAU scenario is calculated.

The **policy scenario** as discussed above leads to a reduction of the GHG-emissions of 27% between 2005 and 2030.
There is an important **difference between the evolution of passenger and freight transport**: the GHG emissions of passenger transport are expected to decrease with 51% (2005-2030), while the GHG emissions of freight transport are expected to increase with 3%.

The **BAU scenario** as discussed above leads to a stabilization of the GHG emissions, also with significant **differences between passenger and freight transport**. Passenger transport emissions are expected to decrease with 10% (2005-2030), for freight transport emissions are expected to increase with 19%.

		2005	2013	2014	2015	2016	2020	2025	2030
Broeikasgasuitstoot sector transport	BAU	15,8	15	15,3	16,4	16,3	16,8	16,7	16,9
(Mton CO_2-eq)	BEL	15,8	15	15,3	16,4	16,3	15,7	14,0	11,5
Evolutie broeikasgasuitstoot	BAU		-5%	-4%	3%	3%	6%	6%	7%
ten opzichte van 2005 sector transport	BEL		-5%	-4%	3%	3%	-1%	-12%	-27%

Figure 7: Description of the scenarios (source: Vlaams Klimaatsbeleidsplan 2021-2030).



	INV 2005	INV 2013	INV 2014	INV 2015	INV 2016	BAU 2020	BEL 2020	BAU 2025	BEL 2025	BAU 2030	BEL 2030
Spoor, scheepvaart, gasstations, offroad	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,7	0,7	0,8	0,8
Personenverkeer	9,0	8,6	8,7	9,4	9,2	8,7	8,5	8,4	7,0	8,2	4,8
Goederenverkeer	6,2	5,8	6,0	6,5	6,4	7,1	6,6	7,3	6,3	7,6	5,9

Figure 8: Estimated emissions in the BAU and BEL scenario (source: Vlaams klimaatbeleidsplan 2021-2030).

2.4 Circular Economy

Circular Economy is referred to as one of the transversal measures, like climate mitigation and spatial planning. It is explicitly stated that a transition towards a green and circular economy is necessary to reach the climate targets. The climate problem is not only an energy problem, it is also linked to our increasing demand for materials because of the linear economy of today. It is thus important to look at the climate problem also as a *material problem*.

Different studies have shown that a significant share of the GHG-emissions is related to materials. This accounts as well for passenger transport. Circular strategies can reduce the GHG-emissions, either directly by reducing our transportation, or indirectly by demanding less materials and products to fulfil the same need. This might put into force a real systemic change.

It is important to focus not only on the GHG-emissions that occur in Flanders (*territorial perspective*), but to look also to the GHG-emissions that occur worldwide due to our Flemish consumption (*footprint perspective*). Footprint indicators allow to identify major impacts in the complete value chain of Flemish consumption and reveal burden shifting (if specific measures lead to decreasing GHG-emissions in Flanders but increasing GHG-emissions abroad). It is thus meaningful to complement the territorial perspective with the carbon footprint when looking to GHG-emissions.

Flanders aims at a reduction of the material footprint of Flemish consumption of 30%. Having targets related to materials consumption is important towards a circular economy which doesn't unbalance the climate.
Concrete measures related to circular economy listed in the Flemish Climate policy plan 2021-2030 are:

- Make sure that products enter the market that have a longer life span, are more repairable, reusable, easier to disassemble and to recycle and include more recycled materials;
- Stimulate production, distribution and consumption models in a way that products are kept in use longer and are used more intensively;
- Further improving separate collection for increasing reuse and recycling;
- Develop new indicators and guidelines, e.g. material footprint of consumption to identify possible GHG-emission reduction over the complete value chain.

Measures that relate to the transition towards a more circular economy are amongst others:

- Development of a Roadmap Circular Economy with specific targets for material consumption, which links circular economy and climate policy.
- Development of a strategy for Collaborative economy, which supports the circular economy and the reduction of material use. This includes the definition of corresponding indicators.
- Stimulating new business models e.g. with a focus on product-service systems.

Chapter 3: Analysis of current state

3.1 Introduction

The literature describes three ways of measuring GHG-emissions:

- consumption footprint;
- territorial emissions;
- production emissions.

The **consumption footprint** uses the consumer perspective starting from all consumption by domestic consumers including the direct or use emissions (i.e. during use), upstream domestic production emissions (indirect) and foreign production emissions (import). The **territorial emissions** are the sum of the domestic direct or use emissions by consumers, the emissions of domestic enterprises in the production processes of products for local consumption (indirect) and foreign consumption (export). The **production emission** focus solely on emissions of domestic enterprises in the life cycle of products for local consumption (indirect) and foreign consumption (export).

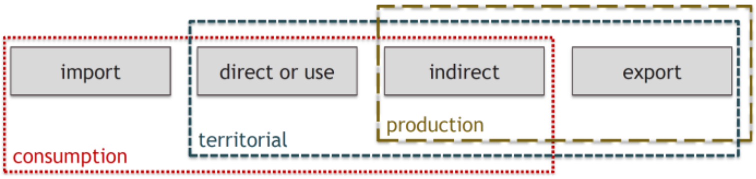


Figure 9: The consumption, production and territorial perspective of environmental flows or footprints.

The targets set out in the Flemish climate policy plan 2021-2030 focus on the territorial perspective [16], however it is stated that burden shifting should be avoided and footprint (consumption) indicators are preferably considered as well to identify potential risk of burden shifting. **Therefor the focus of this report is on the territorial and the consumption perspective.**

3.2 Case Mobility

The assessment in this study is based on a quantitative model that uses available data for the parameters that influence the GHG-emissions of mobility. The following paragraphs discuss the relevant parameters, data sources and data used and their evolution in a Business as Usual (BAU) scenario.

[16] This is according to the international and European climate policy, which is based on reduction targets on a country (territorial)-level.

3.2.1 Difference in scope between this paper and the Flemish climate policy targets 2021-2030

To assess the climate impact reduction potential of circular economy strategies specific for mobility, we start from the as is situation in a reference year (2015) and assess the evolution of the GHG-emissions according to different scenario's. The BAU-scenario is defined to have a baseline to compare the other scenarios to. The BAU-scenario defined in this study is as much as possible in line with the BAU-scenario as it has been defined in the Flemish climate policy plan (see chapter 2). The basic data (e.g. number of vehicles, number of vehicle kilometres) and the defined trends are the same. This gives comparable results for the trends and absolute values in territorial GHG emissions for the period covered, although the BAU-scenario in the Flemish climate policy plan shows a slightly declining trend, while here the BAU-scenario shows a slightly increasing trend. However, the results of the assessment in this study and the results and targets set out in the Flemish climate policy plan can't be compared directly, as the scope of both differs. The most important differences are the following:

- The Flemish climate policy plan starts from a **territorial perspective**[16] and thus focusses on the GHG-emissions that occur in Flanders. The plan acknowledges the added value of the consumption or footprint perspective although no footprint indicators, trends or targets are included. Specifically for mobility, this means that emissions related to production of cars and fuels are considered only limited as the majority of the car and fuel producing industry is covered by ETS[17] and is located outside Flanders. The assessment in the current study starts from a **footprint or consumption perspective** and thus includes all stages in the life cycle of products (e.g. production of cars, fuels, electricity, lubricants, …) related to mobility. Important remark is that this study excludes the treatment of end of life vehicles but stops at the end of the use phase. The footprint perspective is important to assess for example the electrification of the vehicle park. Attention must be paid to the potential trade off due to the (indirect) environmental impact of production and use of these vehicles. E.g. the environmental impact of the electricity production must be considered, and the type of batteries that are used (production, use and recycling of the batteries).
  To illustrate the importance of the footprint perspective, the resulting GHG-emissions are also presented (i) for a territorial perspective only and (ii) for a footprint perspective subdivided in the different life cycle phases.
- The Flemish climate policy plan looks at the **full mobility domain**, i.e. transport of goods and passenger transport, all different transport modes, private and public transport etc. This study has a narrower scope and only focusses on **passenger transport by car**. The model estimates GHG-emissions for mobility limited to passenger transport by cars only (both private and company cars).
- This study focusses on overall trends, based on expected evolutions for specific parameters. Conclusions and insights from this study only refer to general trends in GHG-emissions and their relationship with the circular economy strategies defined in the scenarios. On the other hand, the Flemish climate policy plan goes much more into detail.

[17] ETS-industry sectors are targeted by European policy.

- This study includes GHG-emissions independently of their origin, hence **biogenic CO_2-emissions** are taken into account as well. The Flemish climate policy plan doesn't include biogenic GHG-emissions. Biogenic CO_2-emissions account for 5-6% of (territorial) in-use emissions of cars[18].

3.2.2 Insights from the Belgian interregional input-output model

The next paragraph discusses briefly the first insights regarding the GHG-emissions of the consumption domain transport (mobility) from a footprint perspective. This is based on calculations with the Flemish IO-model and refers to 2010[19].

The consumption domain transport in Flemish household demand includes (2010 data):
- the yearly expenditures on private cars, motorcycles and bicycles (2.337 kilotons CO_2-eq.);
- the yearly expenditures on fuels and lubricants (4.794 kilotons CO_2-eq.);
- the yearly expenditures on parts, accessories, maintenance and repair of private vehicles (896 kilotons CO_2-eq.);
- public transport incl. air travel (excl. holiday packages; 1.547 kilotons CO_2-eq.); and
- in use emissions (8.433 kilotons CO_2-eq.).

The total carbon footprint of this consumption domain is 18.007 kilotons CO_2-eq or 2.9 t CO_2-eq. per capita.

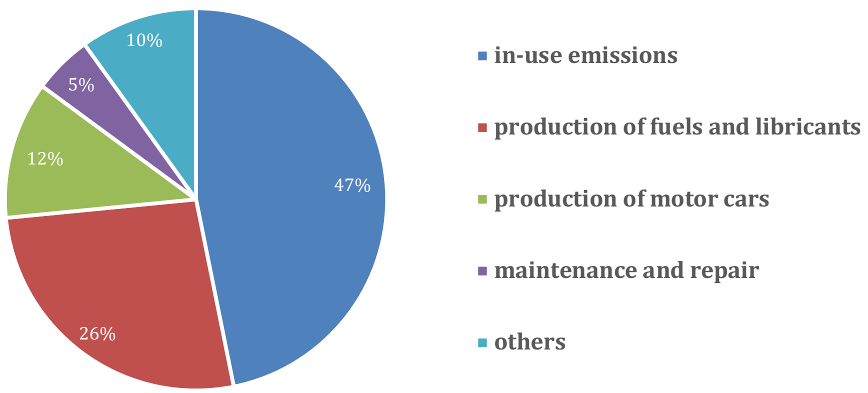


Figure 10: Consumption domains in the carbon footprint of mobility of Flemish households.

The figure above only focusses on passenger transport by Flemish households and excludes all freight transport. The main conclusion from this figure is that the **direct (use phase of fuels) and indirect (production of fuels) emissions related to the fuel consumption of the vehicles** are the most important. Production of the car only accounts for 12% of all GHG-emissions.

[18] Estimate based on calculation model used in this study
[19] Vercalsteren A., Boonen K., Christis M., Dams Y., Dils E., Geerken T., Van der Linden A., Vander Putten E., *Koolstofvoetafdruk van de Vlaamse consumptie*, juni 2017, VITO in opdracht van VMM-MIRA

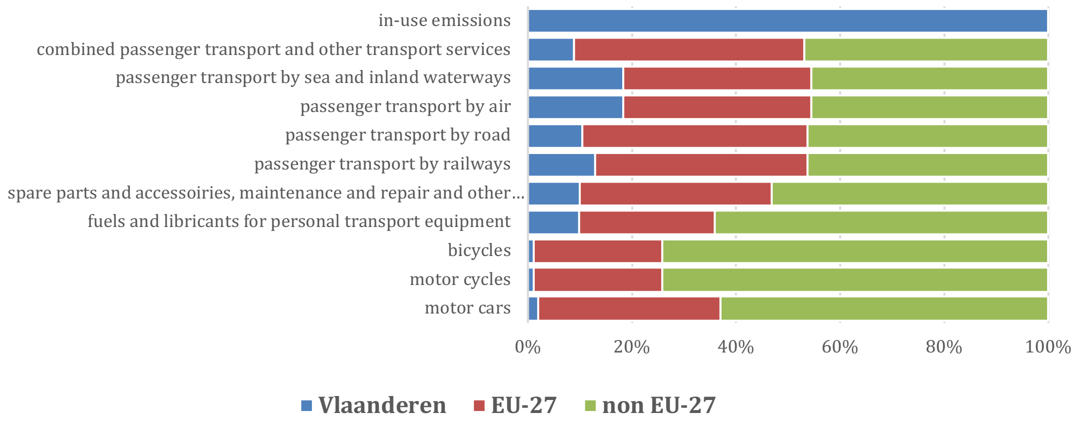


Figure 11: Geographical share of the origin of greenhouse gas emissions in the consumption domain mobility of Flemish household demand[19].

It is also important to know where the emissions occur. The direct emissions when driving vehicles are emitted in Flanders, indirect emissions related to the production of the fuels and cars occur mainly outside of Flanders. The figure above shows for each of the product groups in the consumption domain transport where the emissions take place.

3.2.3 Data supporting a quantitative model for mobility

Based on available data sources, this study estimates general trends in GHG-emissions for different scenarios that focus on circular economy strategies. The assessment is based on a quantitative model that uses available data for relevant parameters and indicators. A description of the parameters, available data sources and derived indicators together with the extrapolation in a BAU-scenario is given below.

New vehicles

Available data on new vehicles

Three parameters describing the new vehicles are used in this study:

- the number of new registrations;
- the fuel technology of newly registered cars;
- the average new fleet GHG-emissions per engine technology (in g/km).

The Ecoscore report[20] provides data on the number of new registrations and the fuel technology of newly registered cars. This dataset is supplemented with data from calculations performed by VITO's mobility experts in the context of the Flemish Luchtplan for Dep. Omgeving[21]. For example, the average new fleet GHG-emissions (per fuel technology) and estimations on BAU future demand in 2020, 2025 2030 for new vehicles (incl. fuel technology) are taken from this source.

[20] Analysis of the 2017 Belgian new and second-hand car fleet – Ecoscore 2018 (Vrije Universiteit Brussel, 2018, http://ecoscore.be/files/2018%20Ecoscore%20Report%20for%20the%20Belgian%20New%20and%20Re-registered%20car%20fleet%20in%202017.pdf).

[21] These calculations were used to support the Flemish climate policy plan targets 2021-2030

Table 1: Available data on new vehicles.

	scope	time
Number of new registrations	Flanders	2008-2017, 2020, 2025 and 2030 trend break between 2011-2012
Fuel technology of newly registered cars	Flanders	2008-2017, 2020, 2025 and 2030 trend break between 2011-2012
Average new fleet GHG-emissions per engine technology	Flanders	2005, 2015, 2020, 2025 and 2030

The number of new registered cars in 2017 in Flanders is 320,817, including cars owned by private persons and companies. The number of new registrations fluctuates; however, it increases by 18% in the period 2012-2017. The fuel technology of these newly registered cars in 2017 is dominated by gasoline (48%) and diesel (46%) (Belgian data). Other fuel technologies are still of minor interest (5%). For example, the battery electric vehicles only represent 2.3% of all newly registered cars.

Extrapolation of data on new vehicles (BAU-scenario)
Based on the available data as discussed in the previous paragraph (see Table 1), extrapolations are made to have a full coverage of the years 2015-2030.

Table 2: Extrapolation of data on new vehicles.

	Extrapolation
Number of new registrations	Assumption of a linear trend in the periods 2018-2019, 2021-2024 and 2026-2029
Fuel technology of newly registered cars	Share taken from the closest year with data available
Average new fleet GHG-emissions per engine technology	Assumption of a linear trend in the periods 2018-2019, 2021-2024 and 2026-2029

Car park
Available data on the car park
Ecoscore[22] reports on data for the total number of vehicles in the Flemish car fleet, including both private and company cars. These data are supplemented with data and BAU-estimations from the VITO's mobility experts in the context of the Flemish Luchtplan for Dep. Omgeving. The parameters used in this study are:

- the number of vehicles in the car park;
- the fuel type distribution;
- the average GHG-emission value of the car park (in g/km).

Table 3: Available data on the car park.

	scope	time

[22] Analysis of the Belgian Car Fleet 2016 (Vito, 2017, http://ecoscore.be/files/Analysis_CarFleet2016.pdf).

Total fleet size	Flanders	2008-2016, 2020, 2025 and 2030 trend break between 2011-2012
Fuel type distribution	Flanders	2008-2016, 2020, 2025 and 2030 trend break between 2011-2012
Average GHG-emission value of the car park	Flanders	2005, 2015, 2020, 2025 and 2030

In Flanders, there are 3.4 million cars in 2016. The total fleet size steadily increased in the period 2012-2016 with 6.3%. Like the fuel technology of the newly registered cars, the car fleet in Flanders in 2016 is dominated by diesel (59%) and gasoline (39%) (based on Belgian data). Other fuel technologies are still of minor interest (<2%).

Extrapolation of data on the car park (BAU-scenario)
The data are extrapolated till 2030. The extrapolation method overrules the available data, to allow changes to the parameters according to the defined scenarios.

Table 4: Extrapolation of data on the car park.

	extrapolation
Total fleet size	assumption of a linear trend in the periods 2018-2019, 2021-2024 and 2026-2029
Fuel type distribution	the values 2017-2030 are calculated based on the distribution of the previous year plus the fuel type distribution of new cars minus the fuel type distribution of deregistered cars
Average GHG-emission value of the car park	the values 2021-2030 are calculated based on the distribution of the previous year plus the average GHG-emissions of new cars minus the average GHG-emissions of deregistered cars

Deregistered cars
Calculated data for the number of deregistered cars
Like the data for the new registered cars, the following parameters are relevant:

- number of deregistered cars;
- fuel type distribution of deregistered cars.

No data are available for the number of deregistered cars in Flanders. For that reason, the number of deregistered cars (2009 till 2030) is calculated, based on the car fleet of the previous year plus the number of newly registered cars in that year minus the size of the car fleet in that year. Based on the same calculation, the fuel type distribution for the years 2009-2016 is estimated[23]. From 2017 onwards, the fuel type distribution of deregistered cars in year x is equal to the number of deregistered cars multiplied by the fuel share in the previous year.

[23] This calculation procedure results in some negative numbers in the deregistered cars per fuel type. The values are negative in case the increase in the car fleet per fuel type is not fully covered by the number of newly registered cars. The negative values are considered to have no substantial impact on the further calculations.

Vehicle kilometres and person kilometres

Data on the vehicle and person kilometres

The Federal Public Office for Mobility and Transport report historical data for the number of vehicle kilometres driven per year[24]. The future demand for vehicle kilometres for 2020, 2025 and 2030 is taken from VITO's mobility experts in the context of the Flemish Luchtplan for Dep. Omgeving. The current and future demand for person kilometres by car is taken from the Federal Planning Bureau[25]. Based on these data the occupancy rate can be calculated. Also, based on the data for the vehicle kilometres driven per year and the total number of cars in the car fleet, the average number of (vehicle) kilometres per vehicle is derived.

Table 5: Available data on the vehicle and person kilometres.

	scope	time
Number of vehicle kilometres	Flanders	1990-2016, 2020, 2025, 2030 trend break between 2012-2013
Number of person kilometres	Flanders	1990-2016, 2020, 2025 and 2030 trend break between 2012-2013

The total number of vehicle kilometres increased in the period 2013-2016 with 4.5% to 45,891 million per year in Flanders in 2016. The total number of person kilometres by car is 59,200 million in 2016 and was fluctuating in the period 2013-2016. This results in an average occupancy rate in 2015 of 1.33 persons per vehicle kilometre. On average a car in Flanders drives 13,484 kilometres in 2015.

Extrapolation of data on the vehicle- and person kilometres (BAU-scenario)

The data are extrapolated till 2030.

Table 6: Extrapolation of data on the vehicle and person kilometres.

	extrapolation
Number of vehicle kilometres	Assumption of a linear trend in the periods 2018-2019, 2021-2024 and 2026-2029
Number of person kilometres	Assumption of a linear trend in the periods 2018-2019, 2021-2024 and 2026-2029
Occupancy rate	Number of person kilometres divided by the number of vehicle kilometres
Vehicle kilometres per car per year	Number of vehicle kilometres divided by the total size of the car fleet

Emission coefficients

Available data on emission coefficients

[24] Kilometers afgelegd op het Belgische wegennet (Federale Overheidsdienst Mobiliteit en Vervoer, 2018, https://mobilit.belgium.be/nl/mobiliteit/mobiliteit_cijfers/kilometers_door_belgische_voertuigen).

[25] FORTRANSP_01 (https://www.plan.be/aboutus/overview.php?lang=nl&TM=27)

The different parameters relate to different phases in the life cycle/value chain of mobility: some relate to production and use (e.g. new vehicles), other relate only to the use phase (e.g. number of vehicle kilometres). Parameters that have impact on the use of the vehicle have a direct effect on the GHG-emissions that occur in Flanders (territorial emissions), while parameters that relate to the production of the vehicles have also an indirect effect on the GHG-emissions outside Flanders (footprint perspective) as production facilities are mostly located outside Flanders.

To estimate the GHG-emissions related to the Flemish mobility, in this report four groups of GHG-emission coefficients are required:

- Emission coefficients related to the production of a car (in CO_2-eq. per car);
- Emission coefficients related to maintenance and repair of a car (in CO_2-eq. per kilometre);
- Emission coefficients related to the production of fuels (in CO_2-eq. per unit of fuel);
- In-use emission coefficients (i.e. driving the car) (in CO_2-eq. per kilometre).

Emissions for the production of one car are taken from the life cycle assessment database Ecoinvent[26]. This database provides GHG-emissions related to the production of different types of cars. Data are available for different fuel technologies (petrol, diesel, electric vehicle) and estimated by a proxy for the other fuel technologies (in kg CO_2 eq. per car). Based on the Flemish input-output model, these emissions are attributed across three regions: 2% to Flanders, 35% to Europe (except Flanders) and 63% to the rest of the world (except Europe). Due to lack of data, the emission coefficients per produced car are considered to be constant and do not increase or decrease over time.

Emissions related to the maintenance and repair of the car are calculated using the Flemish input-output model[27] and are assumed the same for all types of car. The model allows the calculation of GHG-emissions related to the maintenance and repair of the total Flemish car park. The emission coefficient is estimated by dividing the total GHG-emissions of the household final demand domain 'Parts and accessories of private cars, maintenance and repair of private cars and other services related to private cars' by the total vehicle kilometres in Flanders. This emission coefficient includes both the service of maintenance and repair of a car as well as the production of parts and accessories required for the service and maintenance of cars (in kg CO_2 eq. per vehicle kilometre). Based on the Flemish input-output model, these emissions are attributed across three regions: 10% to Flanders, 37% to Europe (except Flanders) and 53% to the rest of the world (except Europe). In this report, the emission coefficients per produced car are a constant number and do not increase or decrease over time.

Emissions related to the production of fuels are taken from the life cycle assessment database Ecoinvent. This database provides GHG-emissions per unit of fuel for the different types of fuel (in kg CO_2 eq. per l, kg or kWh depending on fuel type). The GHG-emissions per unit of fuel are multiplied by the fuel consumption of a car (per fuel type) per vehicle kilometre (data also from Ecoinvent[26]) Based on the Flemish input-output model, these emissions are attributed across three regions: 10% to Flanders, 26% to Europe (except Flanders) and 64% to the rest of the

[26] Ecoinvent version 3.4.

[27] Belgian interregional input-output model (2010 data) extended with Exiobase 2.0 world input-output model (2007 data).

world (except Europe). Due to a lack of data the GHG-emissions per unit of fuel production are considered constant over time. However, the amount of fuel consumed per driven kilometre (see Table 7 for assumption in year 2015) is decreasing, based on the evolution of the GHG-emissions of a car of that fuel type (see Table 4).

Table 7: Average fuel consumption of passenger cars per fuel type (source: Ecoinvent 3.4).

fuel type	average fuel consumption (year 2015)
diesel (L per 100 km)	6.6
gasoline (L per 100 km)	8.4
diesel (hybrid) (L per 100 km)	5.0
gasoline (hybrid) (L per 100 km)	6.3
liquefied petroleum gas (L per 100 km)	3.0
compressed natural gas (kg per 100 km)	9.8
battery electric vehicle and others (kWh per 100 km)	19.9

Emissions related to the use phase are based on the average GHG-emission value of the car park multiplied by the total vehicle kilometres. This source is already explained above.

Chapter 4: Definition and analysis of scenarios for mobility

4.1 Definition of scenario's

Starting from the prognoses and targets defined in the Flemish policy plan 2021-2030, three future scenarios are defined for the transport sector for which the effect on GHG-emissions is assessed. GHG-emissions are calculated from a territorial and footprint perspective.

This study focusses on passenger transport by car only, this is reflected as well in the scenario's. Each scenario focusses on a specific strategy (linked to specific parameter), e.g. electrification of the car park is only focussed on in the Technofix scenario, not in the CCS and LCS scenario. This allows to better assess the individual effect of a specific change/strategy and to create a better insight in the efforts required to reach a specific target or implement a specific strategy.

In total four scenarios are defined:

1. *Linear BAU scenario*
   In this scenario the values are based on the available data and extrapolations provided in Table 1 to Table 7. This scenario serves as a reference and is comparable to the BAU-scenario defined in the Flemish climate policy plan.
2. *Technofix scenario (TEC) –100% new EV in 2030*
   This scenario assumes that the mobility parameters are equal to the BAU-scenario. Also, the demand for mobility (number of person and vehicle kilometres) and the number of cars keep evolving as in the BAU-scenario. The only difference is the technology switch of the cars. It is assumed that by 2030 only electric vehicles are sold. The linear increase starts in 2020 and in 2030 100% of the new vehicles sold are battery electric vehicles. The other fuel technologies are gradually phased out.
3. *Linear climate scenario (LCS) – Drastically reduce demand for car transport to reach climate target in 2030*
   The starting point of this scenario is that the climate goal for passenger road transport is reached by 2030 (-51% of territorial GHG-emissions compared to the 2015-value). This target is achieved by driving less vehicle kilometres, and by using more energy efficient vehicles. This scenario doesn't include an electrification of the car park. The occupancy rate and the number of vehicle kilometres per car are assumed equal to the BAU-scenario, so cars are not used more intensively. With regard to energy efficiency of the vehicles, from 2020 onwards the CO_2-emissions of new vehicles are assumed to be 10% lower compared to the BAU-scenario for all types of cars. Also, from 2020 onwards, the number of vehicle kilometres linearly declines to a certain value in 2030 required to achieve the climate impact reduction for passenger road transport. This change will require a decline in the total number of vehicles, the number of new vehicles and an increase in the number of deregistered cars. Because the occupancy rate is kept equal to the BAU-scenario, the number of person kilometres will also decline because of a decline in the total number of vehicle kilometres.

This scenario assumes a drastical decrease in the demand for passenger transport by car. This might be accompanied by a shift from car to other transport modes, but the climate change impact of this modal shift is not included in this assessment.

4. *Circular climate scenario (CCS) – Drastically increase occupancy rate by implementing circular strategies (sharing, pooling, …) to reach climate target in 2030*

   Like the LCS this scenario assumes again that the climate goal for passenger road transport is reached by 2030 (-51%). Additional circular economy strategies are implemented to reduce the effort requested from consumers, although a significant change in behaviour remains necessary. Due to a wide implementation of car sharing systems, carpooling etc. this scenario assumes no decrease in demand for passenger transport by car (total number of person kilometres is assumed equal to the BAU-scenario).

   In this scenario the climate impact of mobility decreases because less vehicle kilometres are driven, and vehicles become more energy efficient. This scenario doesn't include an electrification of the car park. Compared to the linear climate scenario, the number of vehicle kilometres per car increases, so cars are used more intensively during their lifetime. It is assumed to be doubling in 2030 compared to the BAU-scenario. Between 2020-2030 the model assumes a linear increase between the 2019-value and the doubled value in 2030. Additionally, from 2020 onwards, the CO_2-emissions of new vehicles are assumed 10% lower compared to the BAU-scenario. Also, from 2020 onwards, the number of total vehicles kilometres declines to a certain value to achieve the climate goal for passenger road transport emissions. This change will be accompanied by a decline in the total number of vehicles, the number of new vehicles and an increase in the number of deregistered cars. In this scenario the occupancy rate increases as the same demand for mobility (i.e. person kilometres) is provided by much less vehicle kilometres.

In all scenarios the changes are applied from 2020 onwards. If goals are set for 2030, the changes in years 2020-2029 are assumed to change linearly between the 2019 and the 2030 value.

Two checks are implemented in the model: the occupancy rate cannot exceed five and the number of vehicle kilometres per car per year cannot increase unlimited. Considering an average lifetime of a car of 8 year and 11 months[28], the vehicle kilometres should remain technically realistic.

[28] https://www.febiac.be/public/statistics.aspx?FID=23&lang=NL

	Linear BAU scenario	*Technofix scenario*	*Linear climate scenario*	*Circular climate scenario*
Total car park total size (number of cars)	2020, 2025 and 2030 from data source; assumption of a linear trend in the periods 2021-2024 and 2026-2029		***calculated: total number of vehicle kilometres divided by the average number of vehicle kilometres per car per year***	
Total car park fuel technology (in percentages (share))	calculated based on distribution in year x-1, the new register cars in year x and the deregistered cars in year x			
Total car park GHG-emissions (in gram CO_2-eq. per kilometre)[29]	calculated based on values in year x-1, the new register cars in year x and the deregistered cars in year x			
newly registered cars total size (number of cars)	trend 2012-2017 is extrapolated		***calculated: the average ratio in the period 2015-2019 between the number of new vehicles and the total size of the car park is used to estimate the number of new vehicles in the period 2020-2030***	
newly registered cars fuel technology (in percentages)	2020, 2025 and 2030 from data source; assumption of a linear trend in the periods 2021-2024 and 2026-2029	***in 2030 the share battery electric vehicles in new vehicles is 100%; in the period 2020-2029 a linear increase between the 2019-value and 100% in 2030 is assumed; the other fuel technologies are gradually phased out***	2020, 2025 and 2030 from data source; assumption of a linear trend in the periods 2021-2024 and 2026-2029	
newly registered cars GHG-emissions (in gram CO_2-eq. per kilometre)	2020, 2025 and 2030 from data source; assumption of a linear trend in the periods 2021-2024 and 2026-2029		***emission factors are 10% lower compared to the BAU-scenario***	
deregistered cars total size (number of cars)	calculated based on the car fleet of the year x-1 plus the number of newly registered cars in year x minus the size of the car fleet in year x			
deregistered cars fuel technology (in percentages)	years 2009-2016: calculated based on the car fleet of the year x-1 plus the number of newly registered cars in year x minus the size of the car fleet in year x. 2017 onwards: the fuel type distribution of deregistered cars in year x is equal to the number of deregistered cars multiplied by the share of the fuel type distribution in the previous year.			
number of vehicle kilometres (in kilometres)	trend 2013-2016 is extrapolated		***2030: the number of vehicle kilometres linear declines to a certain value in 2030 to achieve the climate goal for passenger road transport emissions of -51% (compared to 2005); 2020-2029: a linear increase is assumed between the 2019 and the 2030 value***	

[29] GHG-emissions is estimated as the total CO_2-equivalent (kg) including emissions from biofuels.

number of person kilometres **(**in kilometres per person)	2020, 2025 and 2030 from data source; assumption of a linear trend in the periods 2021-2024 and 2026-2029	***calculated: number of vehicle kilometres multiplied by the occupancy rate***	***kept equal to the values in the BAU-scenario***
occupancy rate (in person kilometres per vehicle kilometres)	calculated: number of person kilometres divided by the number of vehicle kilometres	***kept equal to the values in the BAU-scenario***	**calculated: number of person kilometres divided by the number of vehicle kilometres**
number of vehicle kilometres per car (in kilometres per car)	calculated: number of vehicle kilometres divided by the total size of the car fleet	***kept equal to the values in the BAU-scenario***	***doubles in 2030 compared to the BAU-scenario; 2020-2029: a linear increase is assumed between the 2019 and the 2030 value***

Tekst in bold and italic is different compared to BAU-scenario

The GHG-emissions are derived based on the following formulas:

$$GHG\ emissions_{production\ of\ vehicles, year\ y} = share\ in\ new\ vehicles_{fuel\ type\ x, year\ y} \times number\ of\ new\ cars_{year\ y} \times emission\ coefficient\ of\ production\ of\ new\ cars_{fuel\ type\ x}$$

$$GHG\ emissions_{repair\ and\ maintenance, year\ y} = share\ in\ the\ car\ park_{fuel\ type\ x, year\ y} \times size\ of\ the\ car\ park_{year\ y} \times number\ of\ vehicle\ kilomters\ per\ car_{year\ y} \times emission\ coefficient\ of\ maintenance\ and\ repair_{fuel\ type\ x}$$

$$GHG\ emissions_{production\ of\ fuels, year\ y} = share\ in\ the\ car\ park_{fuel\ type\ x, year\ y} \times size\ of\ the\ car\ park_{year\ y} \times number\ of\ vehicle\ kilomters\ per\ car_{year\ y} \times fuel\ efficiency\ of\ a\ car_{fuel\ type\ x, year\ y} \times emission\ coefficient\ of\ production\ of\ one\ unit\ of\ fuel_{fuel\ type\ x}$$

$$GHG\ emissions_{in\ use, year\ y} = share\ in\ the\ car\ park_{fuel\ type\ x, year\ y} \times size\ of\ the\ car\ park_{year\ y} \times emission\ coefficient\ in\ use\ phase_{fuel\ type\ x} \times number\ of\ vehicle\ kilomters\ per\ car_{year\ y}$$

4.2 Impact of the scenarios on the mobility parameters

This paragraph presents the evolution of the key parameters that influence the climate change impact of mobility according to the four scenarios.

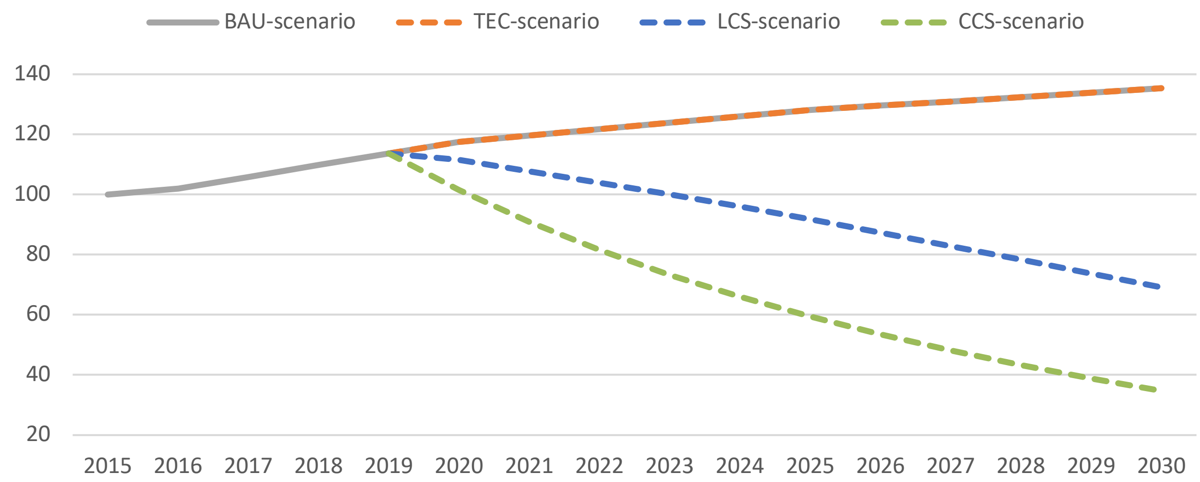


Figure 12: Size of the car park (number of passenger cars; private + company).
(indexed values; 2015 = 100)

The *size of the car park*, 2015-value is 3,362,840 cars, differs substantially between the scenarios. The BAU- and TEC-scenario show an increasing trend until 2030, which is a consequence of the continuation of the historic trend (starting point). The LCS- and CCS-scenario result in a shift in trend. Their implementation requires a drastic change in the number of vehicles in Flanders. Although the demand for passenger transport by car is higher in the CCS-scenario than in the LCS-scenario, much less vehicles are required. This is due to the more efficient use of vehicles, both in terms of vehicle kilometres over the lifetime and in terms of average number of passengers per car (and thus more passenger kilometres).

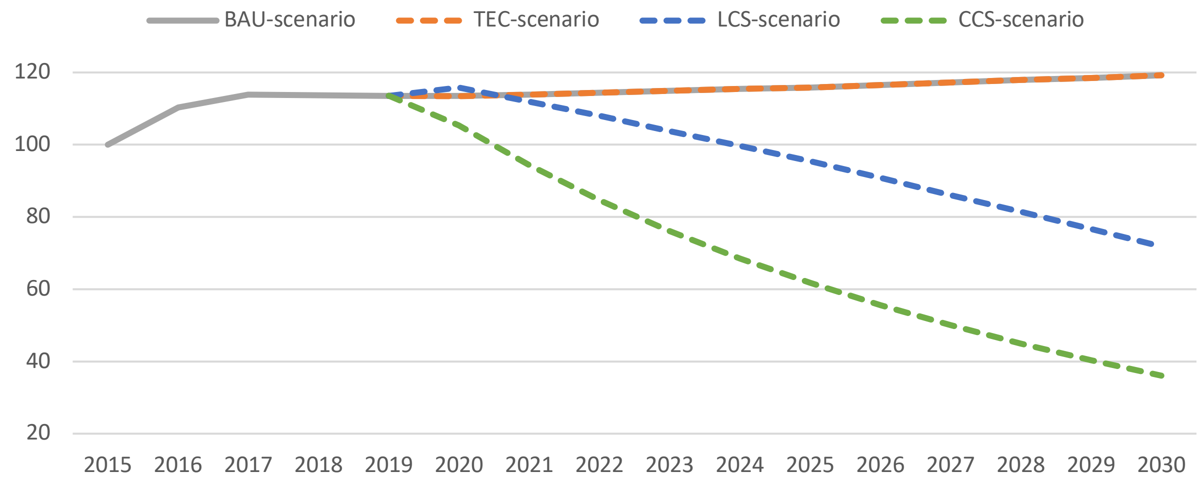


Figure 13: Number of newly registered cars (number of passenger cars; private + company). (indexed values; 2015=100)

The *number of newly registered cars*, 2015-value is 281,771 cars, differs substantially between the scenarios. The trend presented on the graph reflects the assumptions taken in the different scenarios and follows the trend of the total car park (Figure 12). The BAU- and TEC-scenario assume no reduction of the car park. The LCS-scenario requires a decrease of newly registered cars as the total number of vehicle kilometres is required to decrease and the average number of vehicle kilometres per car remains unchanged. The CCS-scenario requires a more efficient use of the car park and for that reason the number of newly registered cars is significantly reduced.

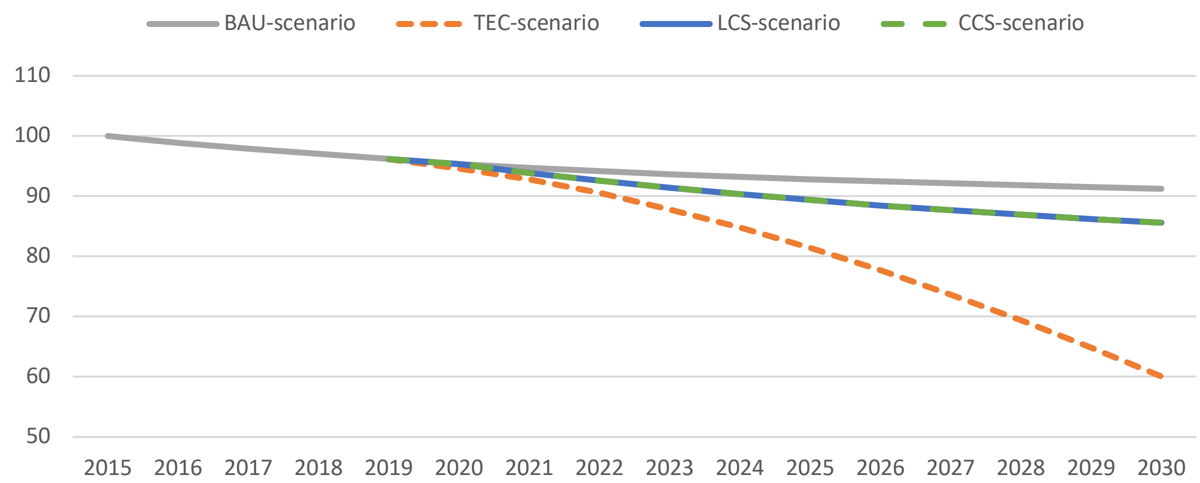


Figure 14: In-use GHG-emissions per vehicle kilometre of the average car in the car park (indexed values; 2015=100))

The *in-use GHG-emissions of an average car*, 2015-value is 180 grams per vehicle kilometre, shows a downward trend in all scenarios. This value is calculated by the ratio of the total in-use GHG-emissions and the total number of vehicles in the car park and is as such influenced by the technology/fuel type of the car in the car park. This clarifies the strong reduction of GHG-emissions per vehicle kilometre in the TEC-scenario, as this scenario assumes new electric vehicles to be 100% battery electric by 2030 and thus a large 'electrification' of the car park. Note that in this scenario the efficiency of the combustion engine technology is considered to not further increase, assuming that car producers focus their innovation on improving EV technology and not on combustion engines as they are expected to leave the market. The LCS- and the CCS-scenario only assume the same fuel technology of newly registered cars as the BAU-scenario but with a 10% efficiency increase. That is reflected in the trend for the average car in the park shown on the graph for these scenarios.

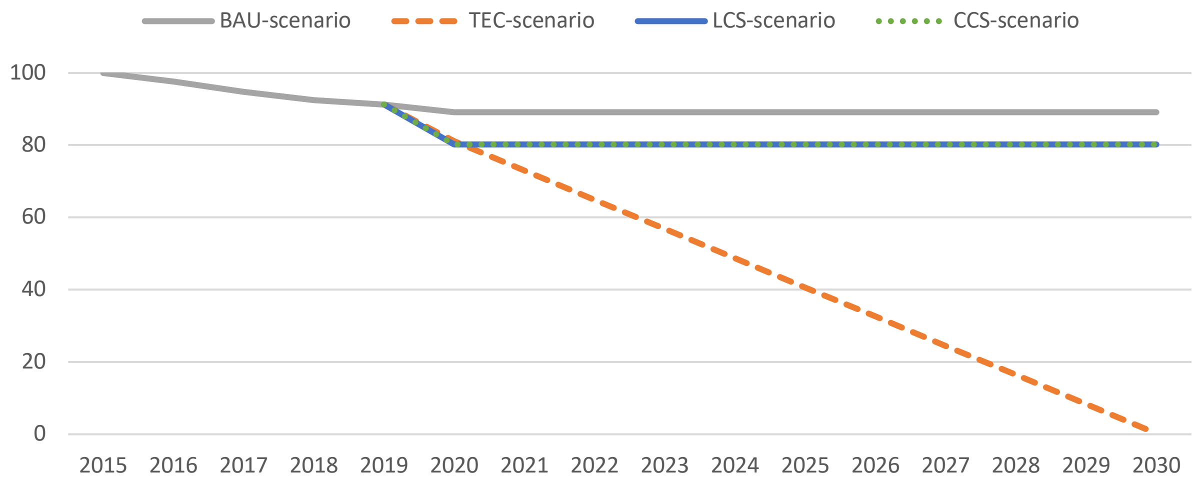


Figure 15: GHG-emissions per kilometre of the average newly registered car. (indexed values; 2015=100).

The *in-use GHG-emissions of an average newly registered car* are in all scenarios lower than the value of 2015 (177 grams per kilometre). This graph reflects the assumptions made when defining the scenarios. The LCS- and CCS-scenario assume a 10% efficiency increase in 2020 compared to the BAU-scenario. The TEC-scenario assumes that between 2020 and 2030 newly registered cars will be more and more electric following a linear trend until 100% in 2030.

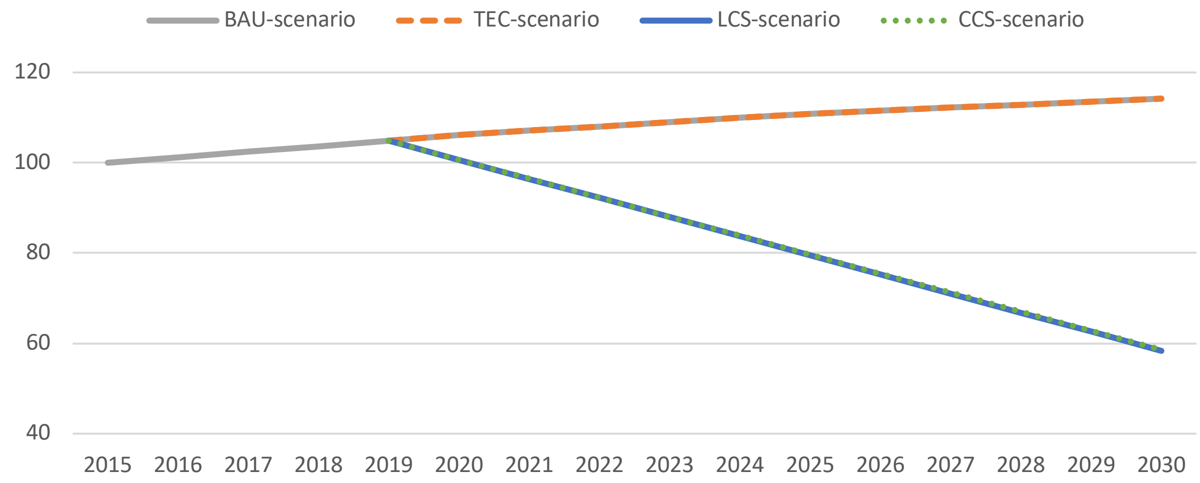


Figure 16: Total number of vehicle kilometres by car.
(indexed values; 2015=100).

The *total number of vehicle kilometres*, 2015-value is 45,343 million kilometres, differs substantially between the scenarios. The BAU- and TEC-scenario show an increasing trend, which is a continuation of the historic trend. The LCS- and CCS-scenario result in a shift in trend. Their implementation requires a drastic change in the total vehicle kilometres in Flanders. This doesn't mean that the demand for passenger transport by car is the same in both scenarios, as there is a significant difference in the way cars are occupied (occupancy rate). That becomes clear when looking to the total person kilometres presented in the next figure.

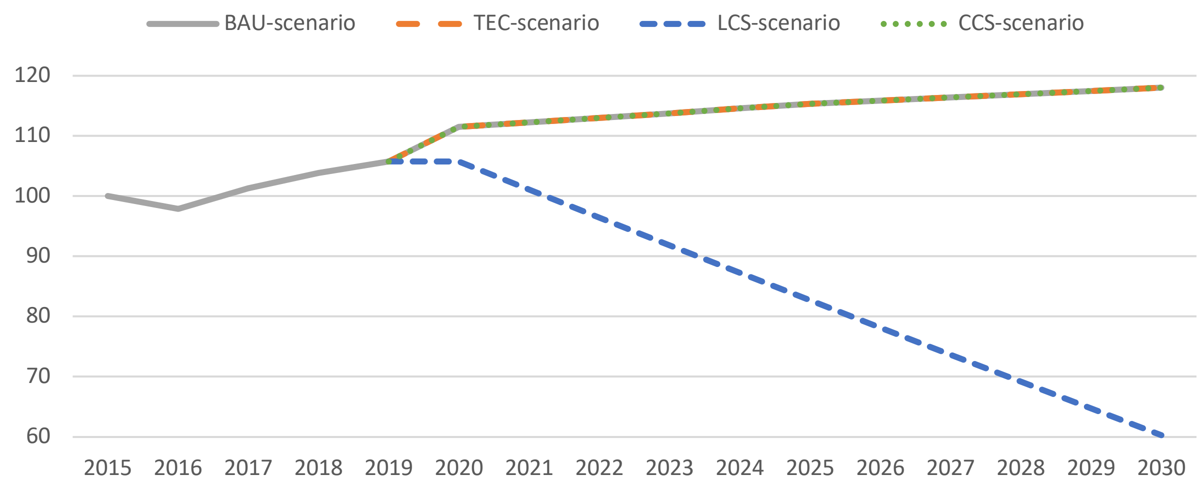


Figure 17: Total number of person kilometres by car (indexed values; 2015=100).

The *total number of person kilometres*, or the need for mobility (by passenger car) for Flanders is 60,478 million kilometres (2015-value). The BAU-, TEC- and CCS-scenario show a slowly increasing trend. One potential adverse effect of the TEC-scenario could be that the total person kilometres increase because the fuel costs are lower (i.e. electricity versus fossil fuels). This underlines the importance of a specific policy accompanying the electrification of the car fleet. Also sharing systems can respond to this potential adverse effect because they let consumers pay per use. The LCS-scenario requires a sharp decrease in the demand for passenger car transport to meet the territorial climate targets. The CCS-scenario, which also meets the territorial climate targets, allows the demand for passenger car transport to slowly increase however. A boundary condition for this is the need to double the occupancy rate (see Figure 18), which shows the difficulty of maintaining this demand.

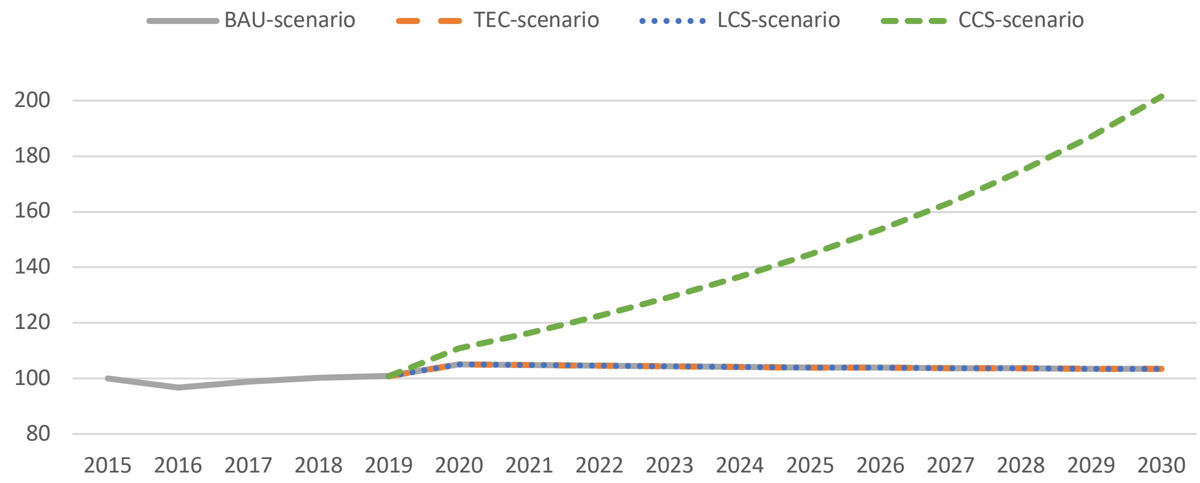


Figure 18: Occupancy rate. (indexed values; 2015=100).

The *occupancy rate* shows the average number of persons per vehicle kilometre. The 2015-value is 1.33 persons per vehicle kilometre. The BAU-, TEC- and LCS-scenario show no large deviation from the 2015-baseline value. In the CCS-scenario however, a doubling of the occupancy rate is required, which illustrates the need for a drastic change in how to fulfil transport needs, while maintaining the demand for passenger car mobility and meeting the territorial climate targets. The occupancy rate required in 2030 according to the CCS-scenario is 2.69, which is still below the defined maximum value of five (check).

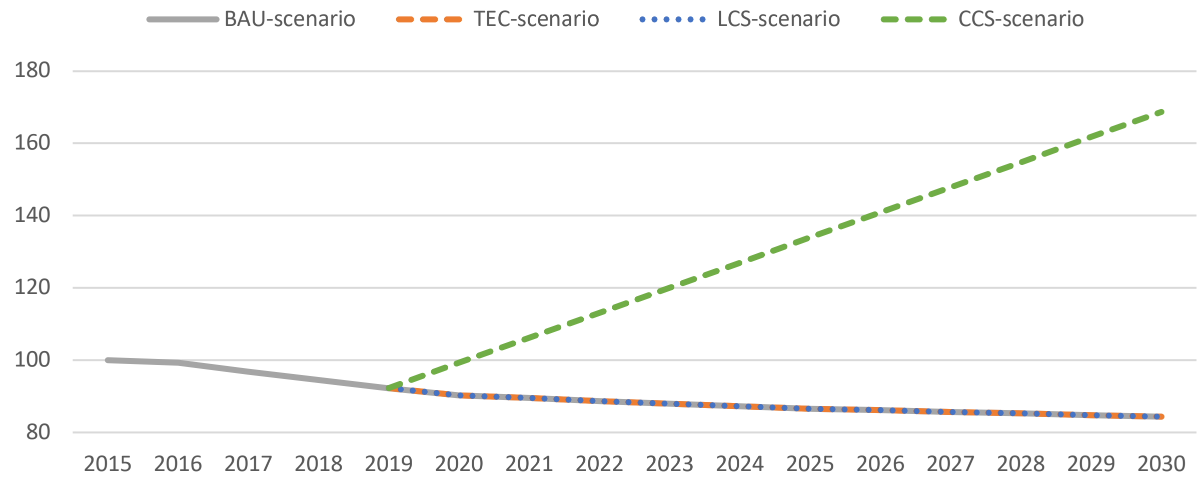


Figure 19: Number of vehicle kilometres per car per year.
(indexed values; 2015=100).

The *number of vehicle kilometres per car* in 2030 according to the CCS-scenario is double of the value according to the BAU-scenario in 2030. The calculated value in the CCS-scenario is 22,751 kilometres. This is assumed to be feasible in combination with an average lifetime of a car of ca. 8 years (check). The TEC- and LCS scenario assume an equal number of vehicle kilometres per car as the BAU-scenario.

4.3 Reduction potential of the scenarios

The figures below show the results of the model calculations for the four scenarios. The first graphs show the trends in GHG-emissions both for the consumption and territorial perspective. Also, figures are included that distinguish the GHG-emissions between the four life cycle phases for each scenario.
It is important to focus only on the general trends that are induced by the scenarios and not to focus on the details of the actual values.

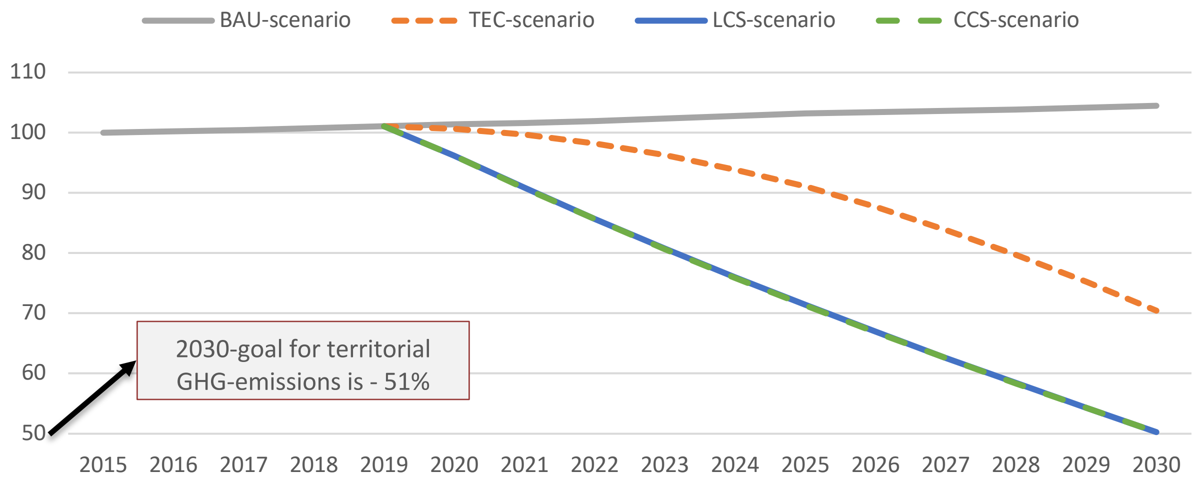


*Figure 20: Territorial GHG-emissions (only emissions in Flanders) of mobility in four scenarios (indexed values; 2015=100) [**territorial perspective**].*

While the territorial GHG-emissions according to the BAU-scenario increase in Flanders towards 2030, the other scenarios show a declining trend of GHG-emissions in a territorial perspective. This is expected as the TEC-, LCS- and CCS-scenario reduce primarily the in-use emissions, which occur in Flanders (see Figure 11). When only a change in technology (TEC-scenario) is introduced, territorial GHG-emissions will decrease, however not enough to reach the climate target as defined in the Flemish climate policy plan[30]. To reach the target, the renewal of the car park needs to be 100% electric from 2020 onwards. The territorial GHG-emissions according to the LCS- and CCS-scenario show that also a shift in our consumption behaviour is required to reach the climate targets. Either the demand for passenger transport by car needs to be reduced significantly (LCS), or the demand needs to be fulfilled in a different, more efficient way (CCS).

[30] These results are based on the assumption that the electricity production mix is constant over the period 2015-2030, and based on the 2015 electricity production mix in Belgium.

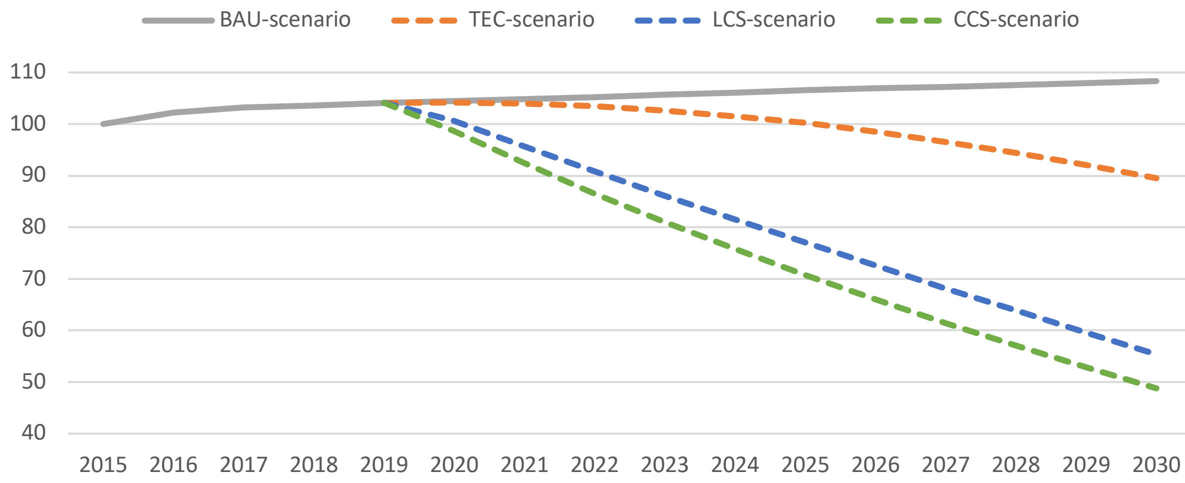


*Figure 21: Footprint GHG-emissions (global emissions) of mobility in four scenarios (indexed values; 2015=100) [**consumption perspective**].*

In a consumption/footprint perspective the same overall trend is visible: according to the BAU-scenario footprint GHG-emissions keep increasing, the other scenarios follow a decreasing trend. The TEC-scenario has more effect on the Flemish GHG-emissions (-30%, see Figure 21) than on the footprint GHG-emissions induced by Flemish demand for passenger transport by car (-10%, see Figure 20). The effect of the CCS-scenario on the GHG-emissions outside Flanders is higher than that of the LCS-scenario, due to the lower need for new vehicles in the CCS-scenario which are mostly produced outside Flanders.

The following four graphs present the footprint GHG-emissions according to each of the scenarios and distinguish the different life cycle stages. This gives additional insights about the life cycle stages that are affected by each scenario.

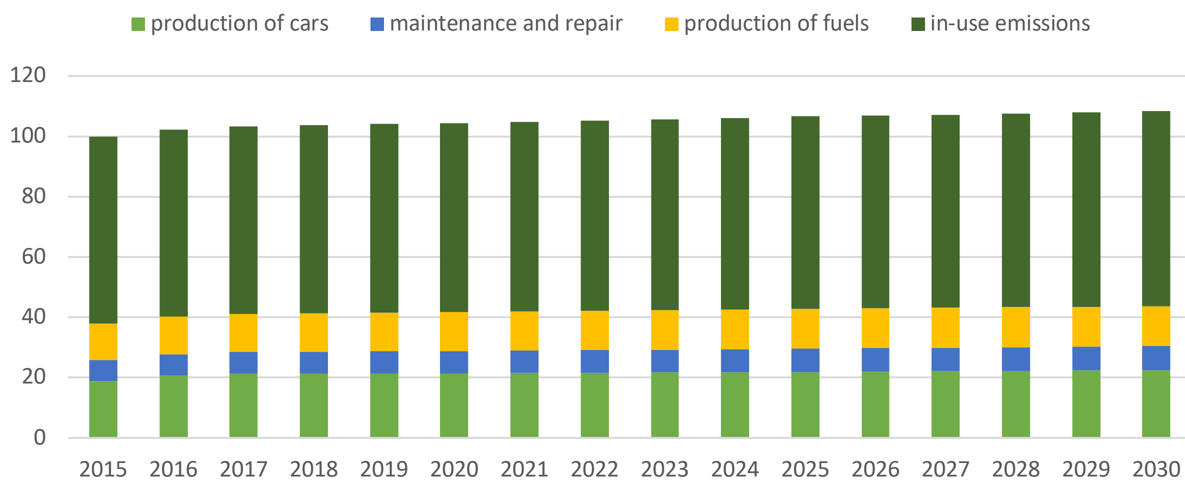


Figure 22: Footprint GHG-emissions (global emissions) of mobility of the BAU-scenario per life cycle phase (indexed values; 2015=100) [consumption perspective].

It is clear that in the BAU-scenario footprint GHG-emissions increase in all stages of the life cycle. More cars need to be produced, which cause more emissions in the *production phase*.

The car park grows, thus more cars need *repair and maintenance* which is reflected in the slight increase of GHG-emissions. The (slight) increase in GHG-emissions during *production of fuels* and *in-use emissions* is due to the increase of total vehicle kilometres driven.

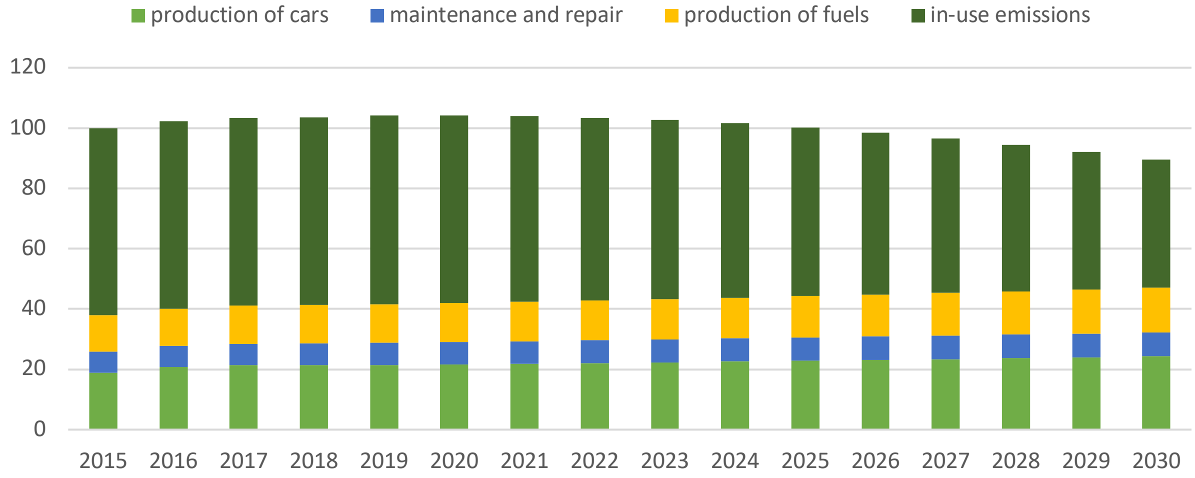


Figure 23: Footprint GHG-emissions (global emissions) of mobility of the TEC-scenario per life cycle phase (indexed values; 2015=100) [consumption perspective].

The emissions in the *production phase of the vehicles* show a small increase, due to the higher GHG-emissions for the production of electric vehicles and batteries compared to traditional vehicles using combustion engines. The emissions related to the *production of fuels* include the emissions of electricity production[31]. The total emissions for production of fuels increase, although per vehicle kilometre less emissions are caused by electricity production compared to production of fossil fuels. The increase of the total emissions is due to the increase of the total vehicle kilometres driven in the TEC-scenario. In this graph, the electricity production mix for the period 2015-2030 is assumed similar to the electricity production mix in 2015. If the electricity production would become less carbon intensive (due to use of renewables), this would be reflected in a reduction of the emissions for production of fuels in the TEC-scenario. The TEC-scenario shows a significant reduction of the *in-use emissions*, which is logical as more electric cars enter the car park, which have no in-use emissions.

A note is to be added on the electricity demand in 2030 in the TEC-scenario. In this scenario in 2030, 36% of the cars in Belgium are electric vehicles. Their combined demand for energy would be ca. 3.4 TWh, which is around 4% of the current net electricity production in Belgium (i.e. 80TWh in Belgium in 2017).

[31] Belgian electricity mix in 2015 is assumed (Ecoinvent v3.4 data)

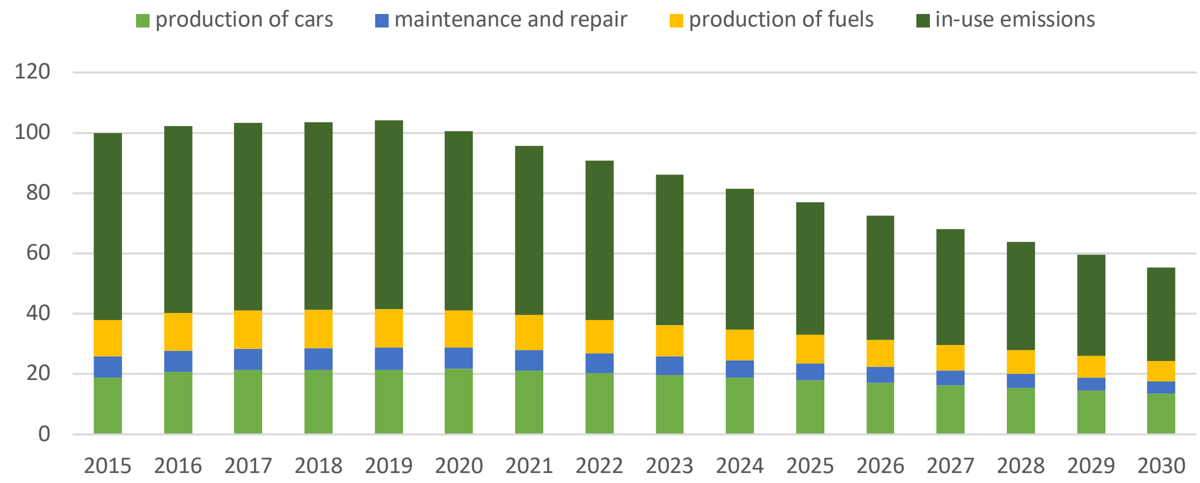


Figure 24: Global warming potential (global emissions) of mobility of the LCS-scenario per life cycle phase (indexed values; 2015=100) [consumption perspective].

Compared to the previous scenarios, the LCS- and CCS-scenario have an impact on all the phases of the life cycle. Emissions related to *production of cars* decline as there is a lower need for new cars, thus less cars need to be produced. This is more distinct in the CCS-scenario because this builds upon a more efficient use of the car park which requires even less cars for the same number of person kilometres compared to the LCS-scenario (see the assumptions in §4.1). The reduced size of the car park causes also a reduction of emissions for *repair and maintenance*. The lower number of vehicle kilometres driven leads to a reduction of the emissions related to *fuel production* and *in-use emissions*.

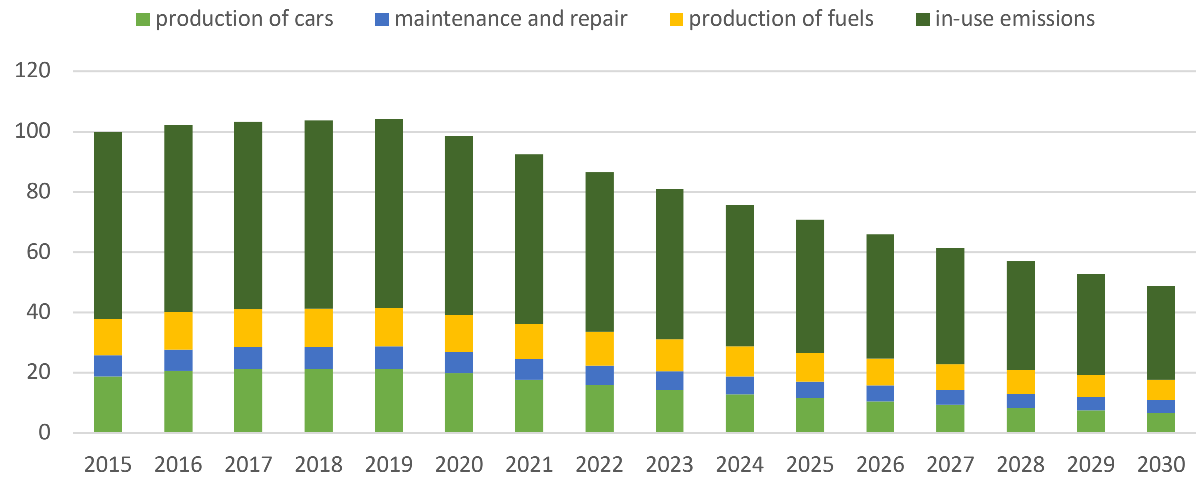


Figure 25: Global warming potential (global emissions) of mobility of the CCS-scenario per life cycle phase (indexed values; 2015=100) [consumption perspective].

Chapter 5: Conclusions

It is important to note that the assessment in this study and the defined scenarios don't predict the actual GHG-emissions until 2030, but merely show the potential of specific changes and the efforts required to reach the targets with regard to climate change impact of passenger transport by car. The assessment gives insight in the challenge and the feasibility of rather extreme scenarios and in the value of circular economy to fulfil our need for mobility in a more climate friendly way.

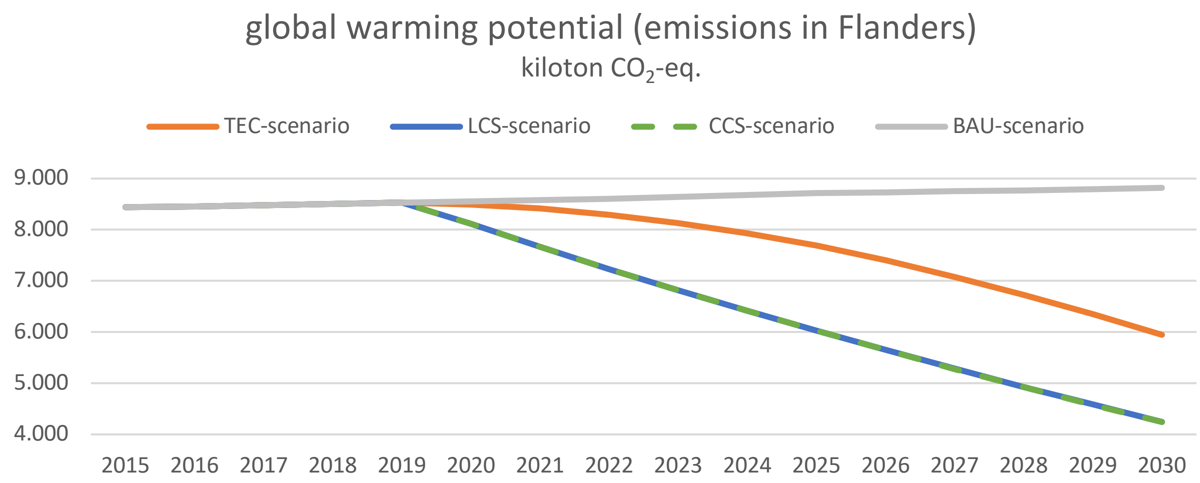


Figure 26: Global warming potential emissions in Flanders (territorial footprint).

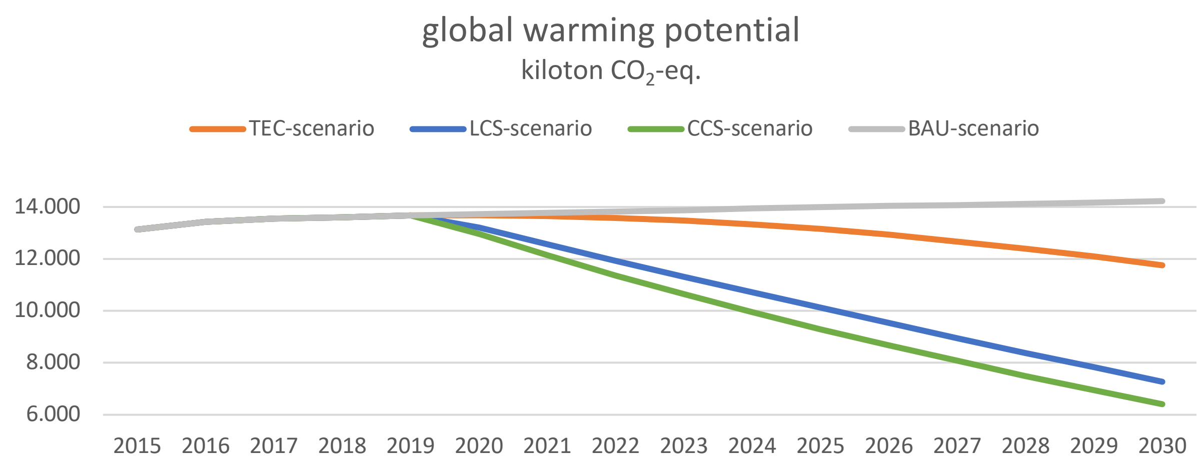


Figure 27: Global warming potential emissions (consumption footprint).

The TEC-scenario clearly shows that electrification only is not sufficient to reach the climate target set in the Flemish climate policy plan (Figure 26). A reduction of the territorial GHG-emissions by 30% is reached instead of 51%. The footprint GHG-emissions are reduced by only 10%. More 'extreme' measures are required to reach the climate target (LCS-scenario), and circular economy strategies can help to facilitate and fulfil our mobility needs in a more

comfortable way (CCS-scenario). In a mobility context, carsharing and ridesharing are concrete examples of circular economy that may lead to this change in behaviour[32]. The additional benefit of circular economy becomes clear when we consider the footprint GHG-emissions in the LCS- and the CCS-scenario: circular economy can take care of an additional reduction without imposing too much constraints to consumers.
Ideally policy measures to reduce GHG-emissions focus on a combination of technological and behavioural changes, while facilitating these transitions (e.g. providing infrastructure and subsidies).

The **footprint perspective** adds valuable insights to the evolution of the territorial emissions. It allows to check for possible trade-offs between changes occurring in Flanders and the indirect effects of these changes/measures outside of Flanders. For example, the TEC-scenario reduces territorial emissions with 30% but causes an increase of more than 20% of GHG-emissions outside of Flanders for the production of the electric vehicles. The LCS- and CCS-scenario cause a 51% reduction of GHG-emissions in Flanders, however the reduction outside Flanders is higher in the CCS-scenario (>51%) than in the LCS-scenario (35%). In both scenarios less new cars need to be produced (mainly situated outside Flanders), but this reduction is more distinct in the CCS-scenario.

The different scenario's show different **potential for climate impact reduction**. The main conclusions are summarized below:

- *TEC-scenario*:
  - Only changing the technology of cars (electric) is not sufficient to reach the climate goals. The overall GHG-emission reduction will be 10% compared to 2015 (footprint perspective), territorial GHG-emissions will be reduced with 30% compared to 2015.
  - An additional reduction is possible by a transition of the electricity production mix to more renewable sources.
  - GHG-emission reduction occurs only during the use phase (in Flanders), GHG-emissions during production of cars increase because GHG-impact for production of electric cars is higher than for traditional cars. When recycling infrastructure for batteries and electromotors is in place, this could (indirectly) reduce the impact of production.
- *LCS-scenario:*
  - The large reduction is caused by the lower demand for passenger transport by car, requiring large efforts from consumers.
  - Overall GHG-emissions are reduced with 45% compared to 2015 (footprint perspective), territorial GHG-emissions are reduced with 51% compared to 2015.
  - GHG-emissions are reduced in all life cycle phases.
- *CCS-scenario:*
  - This scenario and results are comparable to the LCS-scenario but including additional CE-strategies.
  - GHG-emissions are reduced in all life cycle phases.
  - There is an additional reduction of GHG-emissions for production of cars due to the lower number of cars required compared to the LCS-scenario.

[32] Other CE strategies can be reuse of car components, dedicated recycling of EV batteries and engines and the alignment between the needs and the means for mobility (e.g. align the size of a car to the need).

- Overall GHG-emission are reduced with 51% compared to 2015 (footprint perspective), territorial GHG-emissions are reduced with 51% compared to 2015.
- Not captured by the scenarios or the model is the potential additional reduction of GHG-emissions caused by the fact that collaborative systems can better align with consumer needs in terms of e.g. size of cars. They can provide a mix of cars that fit different consumer needs, e.g. small cars that are more energy efficient and less climate intensive to produce can be used for 1 or 2 persons trips (so use of oversized cars is prevented).

The scenarios require **efforts from different actors** (policy, consumers):

- *TEC-scenario:*
  - Investments are required in infrastructure that support and facilitate the use of electric vehicles, e.g. charging stations, dedicated parking space.
  - Investments in infrastructure for recycling of batteries and electromotors are necessary, as due to the limited amount entering the recycling market at this moment recycling infrastructure is not adapted to large volumes.
  - The electricity demand will increase significantly (with ca. 3.4TWh with 36% electric vehicles in 2030 or even ca. 9.5TWh with 100% electric vehicles in 2030; compared to a net electricity production of 80TWh in 2017). Thus, investments to increase the electricity production infrastructure in Belgium/Flanders are required, with a focus on electricity production from renewable sources.
  - Additionally, measures/policy must be in place to stimulate and enable consumers to buy electric vehicles. As long as the prices of EV are higher than traditional cars and no additional measures are in place w.r.t. fuel/electricity prices, consumers will not be motivated to buy EV.
- *LCS-scenario:*
  - This requires high efforts from consumers, as much less transport by car is allowed. Also, more efficient cars are necessary. Consumers need to rely on other alternatives for their mobility: bike, on foot, public transport. This requires a huge behavioral change of consumers and thus needs to be facilitated as much as possible.
  - The government needs to improve spatial planning to reduce the demand for transport and to invest in better public transportation and pedestrian/bike infrastructure, to facilitate the model shift for consumers.
- *CCS-scenario:*
  - This again requires high efforts from consumers as in an extreme scenario the demand for passenger transport by car needs to be fulfilled by much less cars. The available cars need to be used much more efficiently, which requires new systems such as effective car sharing, carpooling systems to be much more widely in place and accepted.
  - Public transportation is important also in this scenario and should be better aligned with car sharing systems.
  - Overall consumers have more options to fulfill their transport need in this scenario (modal shift + collaborative systems).
  - The government needs to invest in improved public transportation and pedestrian/bike infrastructure.

- Policy should be in place to facilitate the 'provision' of collaborative systems that are proven to be beneficial (which may include carpooling and car-sharing) and to stimulate the demand and use of these types of systems by consumers.

The GHG-emissions related to the **EoL treatment of cars**[33] are not included in this assessment, although it is clear that the different scenarios have a different effect on EoL phase.

- *TEC-scenario:*
    - Recycling of electromotors and batteries is an important issue, as this might require changes to the current recycling system. Other materials are present in the engine and the battery (e.g. copper and iron, rare earth elements, …) that might change the cost structure of the recycling system.
    - Although studies give different indications, it is expected that batteries have a shorter lifetime than the EV itself and thus need to be replaced earlier. Recycling or reuse (2nd life in stationary applications) of batteries and electromotors is thus important.
- *LCS-scenario and CCS-scenario:*
    - In both scenarios the number of new cars decreases, as does the number of cars in the car park. This might influence the longer term on the recycling sector, as less EoL vehicles are available.
- In the TEC and LCS scenario (and in BAU) cars are not at the end of their technical life span (number of vehicle kilometers) when they are 'disposed of' in Flanders. A lot of these cars are nowadays exported for 2nd life. In the CCS-scenario the cars are more efficiently used, and they will have reached their technical life span once disposed, thus less cars will be exported for 2nd life.

Although not the subject of this study, scenario's that focus on reducing the GHG-emissions related to mobility have different **economic implications.** The scenarios might cause a reduction or increase in the transport costs for consumers. For example, in the LCS and CCS scenario less cars need to be bought, which corresponds to an 'economic saving' for society. It can be discussed whether this economic saving can be used (by policy) to invest in additional infrastructure or whether this economic saving will be used by consumers for other consumer needs (risk for rebound effects).

Ideally the assessment would not only include GHG-emissions but would focus as well on the **material impact** of these scenarios. It is clear that the scenarios all have an impact on the material footprint as well, although the impact is different.

- *TEC-scenario:*
    - Generally, studies show that electric vehicles use other materials for the engine (e.g. no aluminum for the combustion engine but iron and copper for the electromotor) and for the battery (e.g. lithium). In general, more REE are expected to be used in EV.
    - Less fossil fuels are required during use of the cars, but there will be a higher demand for electricity. This increased demand for electricity requires investments in infrastructure as well, which again has implications for the materials use.

[33] see also: https://www.eea.europa.eu/publications/electric-vehicles-from-life-cycle

- *LCS-scenario and LCC-scenario:*
    - Less cars are required, which directly influences the amount of material needed for the production of new cars in the park and less fossil fuels need to be produced for the use phase of the cars.

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