Centre for Climate and Energy Analyses

# $CO_2$ EMISSIONS REDUCTION POTENTIAL IN TRANSPORT SECTOR IN POLAND AND THE EU UNTIL 2050

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# LIFEClimateCAKEPL

KOBiZE

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# Table of content

## List of tables



## List of figures

# List of abbreviations

| | |
|---|---|
| **CAKE** | Centre for Climate and Energy Analyses |
| **CES** | Constant elasticity of substitution |
| **CGE model** | Computable general equilibrium model |
| **CNG** | Compressed Natural Gas |
| **CPM** | Cost per mile in euro/vkm |
| **d-PLACE model** | Dynamic version of PLACE model (CGE model created in **P**olish **L**aboratory for the **A**nalysis of **C**limate and **E**nergy) |
| **EC** | European Commission |
| **ESR** | Effort Sharing Regulation |
| **EU** | European Union |
| **EU ETS** | European Union Emissions Trading System |
| **EU28** | European Union of 28 Member States |
| **GDP** | Gross Domestic Product |
| **GHG** | Greenhouse Gases |
| **HDV** | High duty vehicles |
| **ICE** | Internal combustion engine (vehicles) |
| **IDEES** | Integrated Database of the European Energy Sector |
| **KOBiZE** | The National Centre for Emissions Management |
| **LDV** | Light duty vehicles |
| **LMDI** | Logarithmic Mean Divisia Index |
| **LPG** | Liquefied Petroleum Gas |
| **MEESA model** | Model for European Energy System Analysis |
| **Non-ETS** | Sectors not covered by the European Union Emissions Trading System |
| **pkm** | Passenger kilometers |
| **tkm** | Tonne kilometers |
| **toe** | Tonne of oil equivalent |
| **$TR^3E$ model** | Transport European Emission Economic Model |
| **WEO** | World Energy Outlook |
| **vkm** | Vehicle kilometers |
| **ZLEV** | Zero- and low-emission vehicle |

# Abstract

Full of challenges and highly dynamic international and European negotiations in the field of the climate and energy policy require well in-depth analysis of policy papers and draft legal acts. In order to be able to reliably evaluate this proposals and to actively participate in its creation, it is necessary to have and use appropriate analytical tools. Such tools enable both the analysis of international proposals and the development of national solutions in the area of climate & energy policy. This was the aim of the creation of the Centre for Climate and Energy Analyses (CAKE) and building modelling tools, including the Transport European Emission Economic Model (TR$^3$E) model for transport sector, which was used for the analyses presented in this document.

The purpose of this paper is to examine different pathways of emission reduction in transport sector in Poland and in the EU up to 2050. In 2015, transport was responsible for almost a quarter of GHG emission in non-ETS in Poland – therefore emission reduction without touching this sector is virtually impossible. Increase in the popularity of electro mobility as well as reduction of $CO_2$ emission in the transport sector is already pursued in different strategic documents and regulation plans.

Main factors determining the $CO_2$ reduction potential in the transport sector are among others the evolution of vehicle prices and the new low emissions technology development. What is important to have in mind, the voluntary transformation of transport sector could be relatively slow. So meeting future EU targets will need an implementation of a mix of voluntary and legally forced transformation measures as well.

In the first two chapters an introduction and a brief summary of European Union and Poland`s transport policy was prepared. Third chapter includes a detailed description of TR$^3$E model and data sources. Then, examined baseline scenario is precisely described in the fourth chapter. Chapter five contains details of four analytical scenarios. Chapter six focuses on the presentation of results for analytical scenarios as well as the detailed data on the cost of electromobility in Poland and the corresponding challenges for the energy sector.


**Keywords:** partial equilibrium, dynamic modelling, transportation, road transport, electric vehicles, aviation, $CO_2$ emissions, fuels, JRC-IDEES, baseline scenario, climate policy, EU ETS, non-ETS, low-carbon transition, electromobility, electric cars, net-zero emissions, climate neutrality

# Executive summary

1. In 2015, transport was responsible for almost a quarter of GHG emission in the non-ETS in Poland. Setting and achieving new $CO_2$ emissions targets without introducing structural and technology changes in this sector is almost impossible. In addition increasingpopularity of electromobility as well as reduction of emission in the transport sector pursued in different strategic documents and regulation plans, will foster this transition.

2. Four different analytical scenarios were prepared to assess possible impact of new technologies development in the transport sector on total sector activity, $CO_2$ emissions and energy needs. It is important to underline that our analysis focused on private cars and LDVs as the main drivers of emissions reduction in transport sector. Technology changes in the field of HDVs, railway are only modelled via emissions intensity improvements. We do not assume green technologies development for HDVs. Three technology progress scenarios (Low, Moderate and High) and one Forced electromobility scenario were prepared.

3. Analytical scenarios are based on several assumptions. These assumptions can be grouped into four different areas:
    - change of vehicle prices up to 2050,
    - change of aviation`s and train`s costs per mile,
    - growth in average mileage for fleet,
    - improvement of emissions intensity.

**Results overview for Poland for 2050**

| | Baseline | Low | Moderate | High | Forced electromobility |
|---|---|---|---|---|---|
| % of electric cars in 2050 | 24% | 39% | 47% | 57% | 80% |
| % of electric LDV`s in 2050 | 25% | 40% | 46% | 54% | 96% |
| $CO_2$ reduction – cars (2050/2015) | -44% | -62% | -68% | -74% | -90% |
| $CO_2$ reduction - LDVs (2050/2015) | +35% | -7% | -14% | -24% | -92% |
| $CO_2$ reduction - total (2050/2015) | -4% | -36% | -40% | -45% | -66% |
| $CO_2$ emissions in 2050 (Mt) | 47.5 | 30.5 | 28.5 | 26.0 | 16.2 |

*Source: CAKE/KOBiZE own presentation*

4. Results for Poland shows substantial potential in $CO_2$ emissions reduction for cars and LDVs. In technology progress scenarios (Low – Moderate – High) the deployment of electric vehicles (LDVs and cars) is on the same level meanwhile in Forced electromobility scenario the share of LDVs vehicles is nearly 100%. LDVs activity in comparison to cars is growing faster in the baseline scenario what is visible in $CO_2$ emissions levels, assuming the same share of electric technology penetration. This is due to the relative costs – cheaper electric vehicles will lure customers to that kind of transport from other modes, like HDVs in case of freight and trains and buses in case of passenger transport. In the baseline $CO_2$ emissions in LDVs will be 35% higher than in 2050 comparing to 2015. In case of cars we assume visible emissions fall by 44%.

5. $CO_2$ emissions decomposition based on LMDI method shows growing importance of change of $CO_2$ emissions level due to structural changes in the transport fleet. Changes (decrease) in carbon intensity of transport activity play important role in $CO_2$ reduction and the level of reduction is higher if the fleet is heavily previously based on "dirty" technologies (ICE - diesel, petrol).

6. Comparison of results of this decomposition for Poland and for the EU shows that in Poland impact of changes in transport activity on the $CO_2$ emissions reduction is at the relatively higher level than in the EU due to growth of transport activity (especially passenger). General conclusion from this decomposition is that the changes in transport sector structure resulting from new low emission technologies development have the major impact on $CO_2$ emissions reduction as well as the changes in carbon intensity of transport activity. This conclusion is founded both for Poland and for the EU.

**Costs/profits overview for Poland for the period 2020-2050 (billions EUR)**

| | Cumulated costs/profits (2020-2050) (billions EUR) | | | | Average (yearly) (2020-2050) (billions EUR) | | | |
|---|---|---|---|---|---|---|---|---|
| **Scenario →** | Low | Mod. | High | FE[a)] | Low | Mod. | High | FE[a)] |
| **Consumer Costs(-)/profits (+)** | 34.8 | 43.5 | 52.4 | - 70.8 | 1.2 | 1.4 | 1.7 | -2.4 |
| **Infrastructure Costs** | -7.8 | -11.6 | -16.0 | -30.9 | -0.3 | -0.4 | -0.5 | -1.0 |
| **State budget revenues (+) /loses (-)** | -8.9 | -15.3 | -22.8 | -66.0 | -0.3 | -0.5 | -0.8 | -2.2 |
| **Total** | **18.1** | **16.6** | **13.6** | **-167.6** | **0.6** | **0.6** | **0.5** | **-5.6** |

[a)] *FE – Forced electromobility scenario*

*Source: CAKE/KOBiZE own presentation*

7. The range of costs associated with the deployment of electric vehicles is very wide and is subjected to large uncertainty. Three categories of costs that are the most frequently mentioned – the costs for consumer, costs of infrastructure and impact (costs) for the state budget were analysed.

8. Change in the user costs of transport is, by and large, the most important position, that affects the total cost and benefits balance of electromobility. In case of "technology progress" scenarios, where the price of electric vehicles is falling, the user grabs all the benefit (both from lower prices of vehicles and through savings on energy), while in the Forced electromobility scenario, user has to pay most of the bill. The expenditures of state are also substantial, as taxes constitute a huge part of the price of oil and petrol, In all scenarios, the loss of state revenues would be substantial and will increase towards the end of the projection period. Costs of infrastructure are somewhat lower than the remaining positions, but also should not be overlooked in the analysis.

9. Savings that will be achieved with the lower price of mobility - travelling 1km with electric vehicle is much cheaper than travelling the same distance with the standard ICE vehicles. These savings occurs, however, much later as infrastructure is already built and fleet is modernized. Therefore, huge initial investments must be made to achieve these savings later. Consequently, to smooth such transition, financial instruments are needed to equalize balance check over time, regardless of the adopted assumptions. This is one of the most important conclusion from the analysis of the costs of electro mobility.

10. The assumption on the vehicle prices plays crucial role in shaping the user cost of mobility in the future. If this costs will fall 1% annually, than the users will save huge amount of resources (from 35 to 50 billion euro in Poland). This is due mostly to the savings on the costs of fuel. In contrary, if electro mobility is to be introduced by the government regulation, user costs will be equal to more than 70 billion euro (2.4 billion annually, on average). Moreover, the cost of infrastructure will add between 0.3 and 1 billion euro annually to the bill and the state budget will need to cover 0.3 to 2.2 billion euro in lost revenue. In general, forced electromobility scenario is the most ambitious one and costs are about twice as high as in "High" scenario, where deployment of electric vehicles is slower. However, also the reduction of $CO_2$ emissions is by 20pp, greater than in any of the "technology progress" scenarios, where switch to electric vehicles is voluntary and induced by price developments.

11. In real future however, the mix of voluntary and some form of forced transformation will be observed. Development of such scenario is great challenge ahead of researchers and policymakers, but one conclusion is certain – if EU want to achieve zero net emission target in 2050, the transformation of transport sector must accelerate and governments need to act now to achieve substantial emission reductions in transport sector in 2050.

## Key policy insights:

- Total $CO_2$ emissions reduction in Poland in the period 2015-2050 vary between **36%** in the Low[1] scenario and **66%** in the Forced electromobility scenario. One must be remembered that emissions reductions occurs mainly in the private cars and LDV`s sector.

- Total $CO_2$ emissions reduction in the EU in the period 2015-2050 vary between **45%** in the Low scenario and **67%** in the Forced electromobility scenario.

- Summary results for Poland show that depending on the analyzed scenario, the financial balance in the transport sector may range from **18.1 billion euro profit** in the Low scenario up to over **167 billion euro loss** in Forced electromobility scenario.

- Consequently, there are possibilities to reduce GHG emissions in transport sector, but this would be quite difficult and can be costly. Moreover, in our simulations, we assume only a small changes in emission intensities for HDVs and air transport – as these means are the main source of emission in 2050, they need to be somehow targeted if net zero emission targets for 2050 are to be completed.

- In general, forced electromobility scenario is the most ambitious one and costs are about twice as high as in "High" scenario, where deployment of electric vehicles is slower (more than **30 bln euro**). However, also the reduction of $CO_2$ emissions is by **20pp**, greater than in any of the "technology progress" scenarios, where switch to electric vehicles is voluntary and induced by price developments.

- Huge initial investments must be made to achieve savings later. Consequently, financial instruments are needed to equalize balance check over time, regardless of the adopted assumptions. This is one of the most important conclusion from the analysis of the costs of electro mobility.

- In real future however, the mix of voluntary and some form of forced transformation will be observed. Development of such scenario is great challenge ahead of researchers and policymakers, but one conclusion is certain – if EU want to achieve zero net emission target in 2050, the transformation of transport sector must accelerate and governments need to act now to achieve substantial emission reductions in transport sector in 2050.

[1] Low, Medium and High scenarios are the three variants of technology progress scenario.

# 1. Introduction and motivation

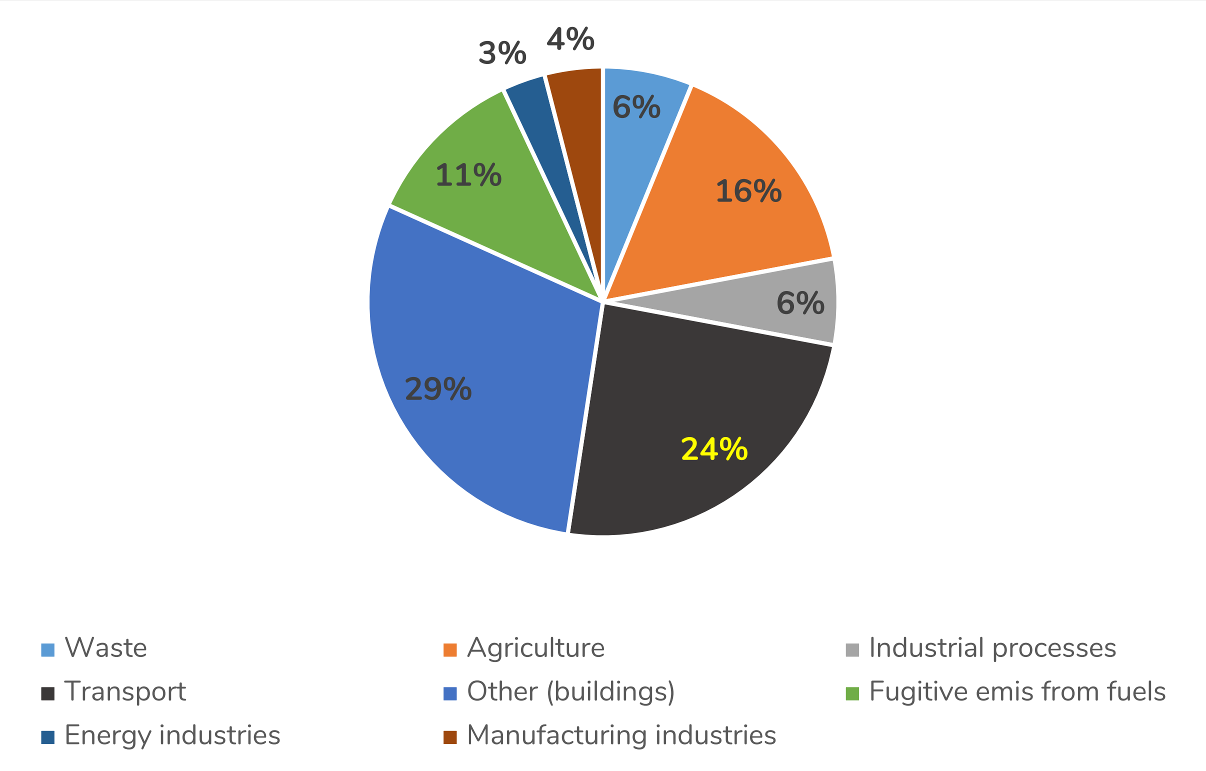
1. Full of challenges and highly dynamic international and European negotiations in the field of the climate and energy policy require well in-depth analysis of policy papers and draft legal acts. In order to be able to reliably evaluate this proposals and to actively participate in its creation, it is necessary to have and use appropriate analytical tools. Such tools enable both the analysis of international proposals and the development of national solutions in the area of climate & energy policy. This was the aim of the creation of the Centre for Climate and Energy Analyses (CAKE) and building modelling tools, including the Transport European Emission Economic Model ($TR^3E$) model for transport sector, which was used for the analyses presented in this document.
2. This report presents the analyses of the development of the fleet and its impact on $CO_2$ emissions and energy system only. It is important to underline that its scope does not cover the needed changes in the infrastructure and corresponding costs.
3. Important publication being entry point for the reflections presented in this report is the European Commission *A Clean Planet for all - A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy* which sets up key elements crucial to achieve by 2050 goals of climate neutral economy.
4. Climate neutral economy or in other words net-zero means a substantial change across the entire EU economy, phasing out mostly the fossil fuels and the other emissions sources wherever possible. The concept of net-zero is set up on the rule that each tonne of $CO_2$ emitted must be matched by a tonne that is removed from the atmosphere.
5. Transport sector represents approximately one third of the final energy consumption in the EU. Moreover, the most used transport technologies rely on the fossil fuels combustion, and current policies and measures up to 2050 will change it only in a limited manner.
6. $CO_2$ emissions data shows that in transport sector emissions were in steady rise and are projected not to fall comparable to other the EU economy sectors (i.e. energy or industry) in the perspective of the year 2030.
7. Recent development of transport sector and targets concerning the EU emissions standards, has shown that in-deep analysis of possible costs and changes in the EU transport branch is more than needed. New policies imply additional costs for the economy to achieve goals and targets in a given time.
8. Especially in the new EU member states important rise in transport activity is being noticed mainly due to higher average economic growth rate than in the old EU countries, growing share of vehicles per capita and development of new infrastructure (mainly road and rail).

9. Nearly 55% of the EU greenhouse emissions are not covered by the EU ETS. Sectors which lay outside of the scope of the EU ETS, including agriculture, buildings and transport are regulated by the Effort Sharing Regulation[2]. Up to 2030 these sectors at the level of the EU must reduce GHG emissions by 30% compared to 2005.

10. The total EU reduction target was allocated between the Member States according to GDP per capita measure. Poland is obliged to reduce emissions by 7% in all non-ETS sectors up to 2030 comparing to the 2005. Of course, this 7% target is not spread equally among non-ETS sectors, but it gives overall look on the country target in the 2030.

11. Transport sector among other non-ETS sectors is characterized by increasing GHG emissions, especially in the recent years. GHG from transport sector in the EU increased between 1990 and 2017 by 19%[3]. Almost one fourth of non-ETS emissions in Poland come from the transport activity (figure 1).

**Figure 1. $CO_2$ emissions in the non-ETS in Poland in 2015 (%)**




*Source: CAKE/KOBiZE own calculation based on EIONET data*

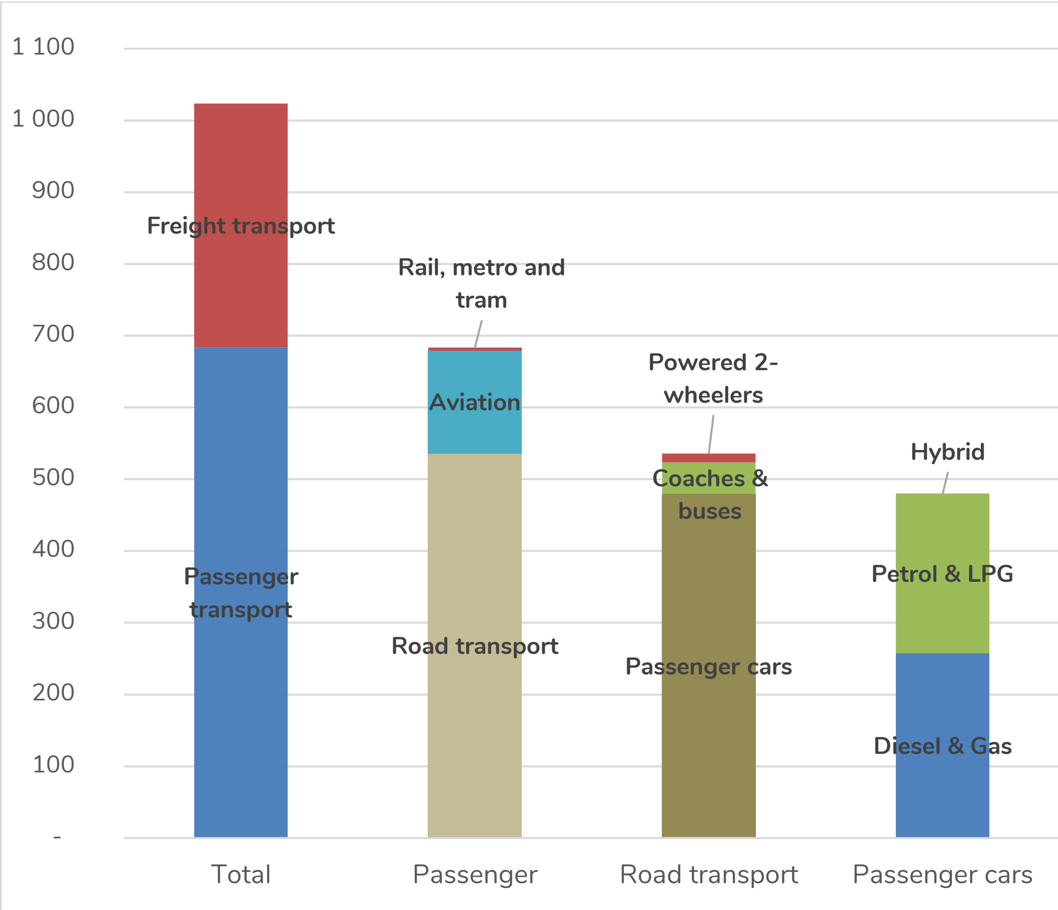
[2] Regulation (EU) 2018/842 - Binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013 (European Commission (2018)).

[3] Annual European Union greenhouse gas inventory 1990–2017 and inventory report 2019, EEA May 2019.

12. According to EEA in 2017 road transport contributed almost 22% of EU`s total $CO_2$ emissions[4]. In the EU within the transport sector the road transportation is responsible for the most GHG emissions (nearly 95%). Aviation, with a share of 2%, the rail - 1% and maritime transport - 2% are less important from this perspective, but still not negligible. The share of the road transport $CO_2$ emissions in Poland is at 6.9%, but between 1990 and 2017 emissions raised by 230%, which is the biggest change among all EU member states (the EU average is at the level of 24%)[5].

13. If we have a look on the emissions structure within the transport sector (figure 2) the most visible feature is that dominant part of the emission comes from the passenger transport (68%). It follows the important share of road transport where dominant fuels are more or less at an equal share of petrol+LPG and diesel+gas. It is worth to underline that aviation emissions show one of the highest growth rate within the EU (13% growth between 2000 and 2015), and together with road transport represent almost 100% of passenger transport emissions.

**Figure 2. $CO_2$ emissions in 2015 in the EU28 from transport sector (Mt $CO_2$)**

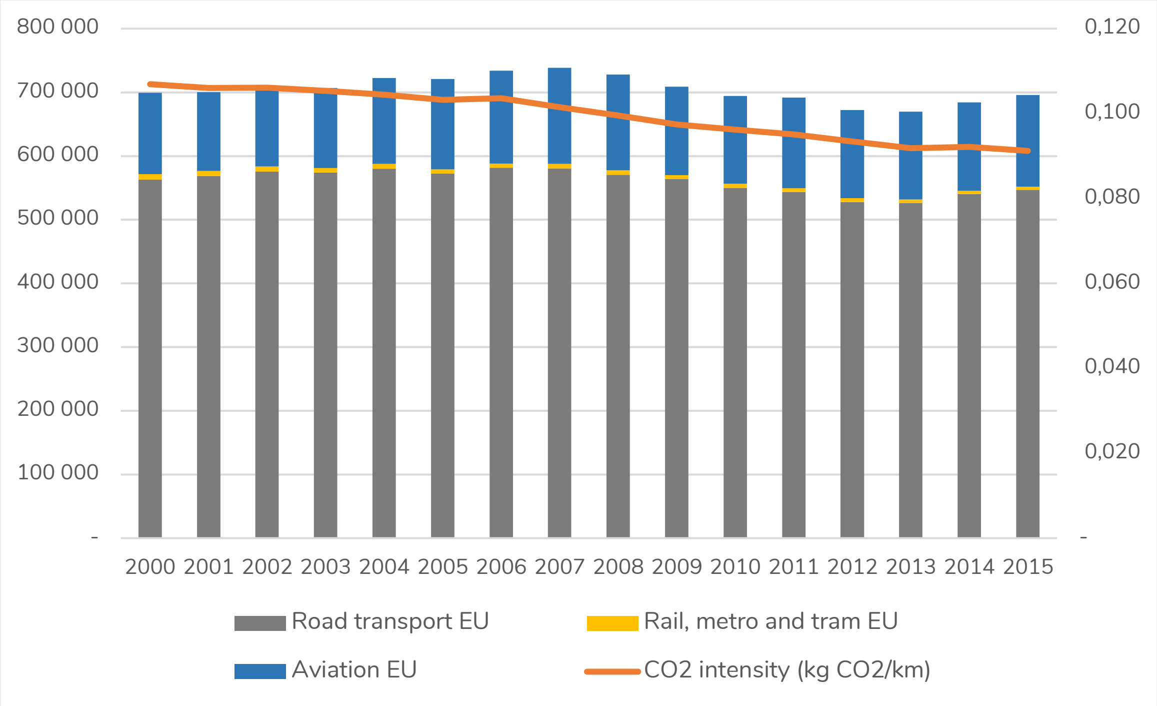



*Source: CAKE/KOBiZE own calculations based on IDEES data*

[4] https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer

[5] Annual European Union greenhouse gas inventory 1990–2017 and inventory report 2019, EEA May 2019

**Figure 3. $CO_2$ emissions in the EU from passenger transport sector (kt $CO_2$)**




*Source: CAKE/KOBiZE own calculations based on IDEES data*

# 2. Legislative background and literature review

## 2.1. EU low emissions vehicles policy

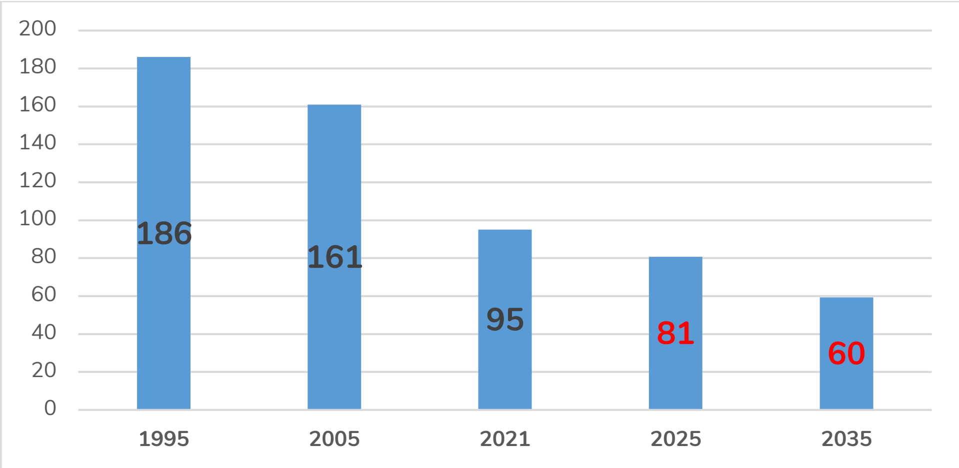
14. Initiatives planned to be prepared and implemented by the European Commission are framed in the European Strategy for Low-Emission Mobility from July 2016 (European Commission (2016a)). Besides strengthening the European economy the main goal of the Strategy is to help in low emission mobility development across the EU member states.

15. The main elements of the Strategy are:

- Increasing the efficiency of the transport system by making the most of digital technologies, smart pricing and further encouraging the shift to lower emission transport modes,
- Speeding up the deployment of low-emission alternative energy for transport, such as advanced biofuels, electricity, hydrogen and renewable synthetic fuels and removing obstacles to the electrification of transport,
- Moving towards zero-emission vehicles as Europe needs to accelerate the transition towards low- and zero-emission vehicles.

16. To achieve its goals in $CO_2$ emissions reductions from transport sector the European Union has proposed or already adopted several legislative measures. Concerning the road transport legal binding targets are divided between cars and light duty vehicles (LDV) from the one side and heavy duty vehicles (HDV) from the other. In the regulation (EU) 2019/631 setting new $CO_2$ emission standards for cars and vans (European Commission (2019a)) targets levels are introduced for new vehicles for the years 2025 and 2030. These targets are defined as a percentage reduction from the 2021 as a starting point.
For cars 15% reduction from 2025 on and 37.5% reduction from 2030 onwards, and for vans 15% reduction from 2025 on and 31% reduction from 2030 onwards (figure 4). Regulation sets a definition of zero- and low-emission vehicles (ZLEV) as a passenger car or a van with $CO_2$ emissions intensity between 0 and 50 g/km.

**Figure 4. Evolution of the $CO_2$ emissions standards for cars in the EU (g $CO_2$/km)[6]**




*Source: CAKE/KOBiZE own presentation based on Regulation 2019/631*

17. Requirements for the HDVs are regulated by the Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 June 2019 setting $CO_2$ emission performance standards for new heavy-duty vehicles and amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC (European Commission (2019b).

18. Regulation sets up a target of 15% lower emissions from the new HDVs than the average emissions in the reference period (1 July 2019-30 June 2020). The average emissions in 2030 have to be 30% lower than the average emissions in the reference period. The review of the Regulation will assess this target in 2022. The HDV regulation recognizes a lorry which has no tailpipe $CO_2$ emissions as the zero emission vehicle.

[6] $CO_2$ emissions standards for 2025 and for 2035 are potential ones, assuming that 95 g/m target in 2021 will be met.

19. Very important issue in the area of road transport is the fuel quality. At the EU level directive on quality of petrol and diesel was implemented[7]. Fuel quality directive applies to fuels used in the road transport (petrol, diesel and biofuels). This legislative act requires a reduction of the greenhouse gas intensity of transport fuels by a minimum of 6% by 2020.

20. Aviation in the EU as the one of the fastest growing sources of $CO_2$ emissions has a special place in the EU legislation. Emissions from the aviation sector are covered by the EU ETS. Regulation (EU) 2017/2392 covers all the European flights between 2017 and 2023[8].

21. On the area of inland and international shipping so far only monitoring, reporting and verification (MRV) measures were set as to better recognition of $CO_2$ emissions levels. Greenhouse gas emissions from international maritime transport are estimated to amount of 940 million tonnes of $CO_2$ per year, representing approximately 2-3 % of total the global GHG emissions. These emissions are projected to increase significantly in the nearest future. Recently, the EU has proposed a new piece of legislation on the fuel consumption from ships[9]. Impact assessment to this draft regulation sets up specific options on the maintaining a single set of MRV requirements at EU level. The proposed action is to ensure the comparability and reliability of $CO_2$ emissions data from ships.

## 2.2. Poland`s electromobility policy

22. Poland is the member state with the highest growth rate of $CO_2$ emissions from the transport sector in the EU. As it was mentioned before, between 1990 and 2017 emissions from road transport raised by 230%. Between 2016 and 2017 emissions raised by 16% which is the highest growth in the all EU member states in that period.

23. Another important feature of Poland`s transport sector is the share of road freight activity within the EU. According to Eurostat, Poland is thus one of the most active haulier countries in international road transport in Europe. Polish carriers have the highest shares in foreign hauliers in 12 Member States and the second highest share in another 10 Member States. Even in geographically distant countries, Polish hauliers remain active: for example, 29% of all tonne-kilometers forwarded by foreign hauliers in the United Kingdom were carried by Polish hauliers[10].

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[7] Directive 98/70/EC of the European Parliament and of the Council of 13 October 1998 relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC (European Union (1988)).
[8] Regulation (EU) 2017/2392 of the European Parliament and of the Council of 13 December 2017 amending Directive 2003/87/EC to continue current limitations of scope for aviation activities and to prepare to implement a global market-based measure from 2021 (European Union (2017)).
[9] European Commission (2019a) Proposal for amending Regulation (EU) 2015/757 in order to take appropriate account of the global data collection system for ship fuel oil consumption data COM (2019) 38
[10] Freight transport statistics - modal split, Eurostat 2019

24. So far several documents or legislative proposals were proposed in Poland in the area of electromobility.

25. Electromobility Development Plan in Poland sets three main goals:

- Creating conditions for development of electromobility of Poles,
- Development of electromobility industry,
- Stabilization of electricity grid[11].

26. Act of 11.01.2018 on the electromobility and alternative fuels regulates the issue of access to the infrastructure and facilities enabling the operation of electric vehicles as well as CNG or LNG vehicles[12]. The quality of fuels and the share of bio-fuels are covered by the act of 6.06.2018[13]. It regulates the obligatory share of bio-fuels and special reporting and verification procedures. As well it sets details of functioning of Low-emissions Transportation Fund.

27. The most recent strategic document is the Strategy for Sustainable Transport Development in Poland[14]. It covers all means of transportation in Poland as well as the interaction between them and proposes solutions for a more efficient and more sustainable sector. Apart from the socio-financial issues the Strategy proposes interventions in limiting the impact of transport sector on the environment in Poland. Special attention was also given to the electromobility and the modal shift in transportation sector. In the area of $CO_2$ emissions limitation from transport sector, the Strategy assumes $CO_2$ emissions in 2030 below 53.11 Mt $CO_2$, what equals 17% reduction from 2017 level. Target of the final energy use, was set in such a way, that final energy use in 2030 cannot be more than 15% points higher in comparison to 2017.

## 2.3. SWOT analysis of electromobility in Poland

28. For better recognition of the situation of transport sector in Poland SWOT analysis was prepared. It attempts to identify strengths and weaknesses and to point out opportunities and threats for electric vehicles development in Poland (table 1).

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[11] Electromobility Development Plan in Poland (Plan Rozwoju Elektromobilności w Polsce „Energia do przyszłości", 16.03.2017 r.)

[12] Act of 11.01.2018 on the electromobility and alternative fuels (Ustawa o elektromobilności i paliwach alternatywnych z dnia 11 stycznia 2018 r.)

[13] Act of 6.06.2018 on Low-emissions Transporation Fund (Ustawa powołująca Fundusz Niskoemisyjnego Transportu, tj. ustawa z dnia 6 czerwca 2018 r. o zmianie ustawy o biokomponentach i biopaliwach ciekłych oraz niektórych innych ustaw)

[14] „Strategy of sustainable transport development up to 2030" (*Strategia Zrównoważonego Rozwoju Transportu do 2030 roku*), adopted on the 24.09.2019 r.

### Table 1. SWOT analysis of electric vehicles development in Poland

| Strengths: | Weaknesses: |
|---|---|
| • Access to the leading vehicle and electric and fuel cell architecture engineering through European funds and projects.<br>• Highly developed public transport services.<br>• Growing share of renewable energy sources.<br>• Fast-growing new transport infrastructure.<br>• First mover advantage. | • Resistance of customers to change.<br>• Electric vehicle portfolio, prices and ranges.<br>• Limited automotive battery and fuel cells technologies.<br>• Consumer choices – individual transport behavior.<br>• Little developed charging infrastructure.<br>• Still lower income in comparison to the rest of the EU.<br>• Large share in sales of secondhand cars.<br>• Relatively old and decapitalized power grid infrastructure. |
| **Opportunities:** | **Threats:** |
| • Savings on fuel could keep money in the PL and ensure energy security.<br>• Need for a better quality of life in PL cities and better air quality and less noise.<br>• Electrification as a solution for GHG emissions reductions in transport sector.<br>• Electric mobility sector is still evolving so PL companies can still play a strong role.<br>• Good public perception of transport sector pollution impact on smog in big agglomeration.<br>• Recognition of electromobility in the EU and its funding opportunities. | • Substantial importance of entry costs in the vehicle industry.<br>• Global competitiveness loss of EU automobile industry.<br>• Higher demand on the electricity from coal could raise the $CO_2$ emissions.<br>• EU market changes and technology imports from other then EU regions.<br>• Competition from Asia or other world regions and imports entering the EU value chains for electric mobility.<br>• Relatively poorly perceived impact of $CO_2$ emissions on climate change in Poland. |

*Source: CAKE/KOBiZE own analysis*

## 2.4. Literature review on future challenges for transport sector

29. Emission reduction in transport sector is becoming a very important area of research and scientific analysis. Both importance of this sector in $CO_2$ emissions share and the new emerging technologies are the main drivers of the recognition of importance of in-depth analysis. In literature a wide range of measures and possible reduction of $CO_2$ emissions path is investigated. Among others, the most common policies are promotion of new, green automotive technologies, implementation of vehicle and fuel standards, as well as introduction of taxes or financial support measures.

30. From the methodological perspective in the analysis in question, several types of economic tools were used. Mostly used were linear optimization models (der Zwaan et al. (2013), Seixas et al.(2015), Thiel et al. (2016), Haasz et al. (2018)). But there are examples of application partial equilibrium model (Ajanovic, Haas (2016)), techno-economic simulation model (Mulholland et al. (2018)) as well as general equilibrium model (Thalmann, Vielle (2019)). In the study of Sorrentino et al. (2014) set of different models were used (mass model, market penetration model, longitudinal vehicle model). So both optimization and simulation methods were applied in this area. Important issue is that all studies shows that the only way of achieving the GHG emissions reductions of transport sector, it is a massive market and behavioral change. Some of the studies are dealing with specific regions (Bahamonde (2015), Thalmann(2019)) but there some which are done for the EU (Seixas(2015), Haasz(2018), der Zwaan(2013), EASAC(2019)) and for the whole world as well (Gota (2015).

31. Research papers in this domain can be grouped into two main categories. First contains reports on GHG ($CO_2$) emissions reduction potential within the transport sector. The second important group of analysis concerns the potential of electric vehicles market growth.

32. Results shows that majority of $CO_2$ emissions reduction takes place in the private cars road transport sector (Haasz(2018).

33. Following EASAC(2019) "*electrification can only deliver its full potential in terms of $CO_2$ emission reductions if it is accompanied by the phasing out of coal-fired and other high-emission power generation plants or possibly fitting them with carbon capture and storage systems*". Transport electrification would require 50% increase of electricity supply, comparing to existing supply (EASAC2019).

34. The target year is the main determinant which vary reduction potentials across the scientific papers. Most of them contain projections of $CO_2$ emissions up to 2030 (ex. Ajanovic (2016)) or 2050 (ex. Seixas 2015)) but there are some showing the emissions development up to 2100 (der Zwaan (2013)).

35. Further improvements of conventional ICE technologies could result in maximum efficiency gains of about 50%, and could only lead to a stabilization of transport

emissions. Therefore this paper shows that a long-term emission reduction target of 65 to 95% cannot be achieved only by improving conventional technology (Hoen(2009).

36. Analysis containing the results at the world level shows 50% reduction potential up to 2030 (Gota (2015)). Comparable results were provided for Germany by Rodt (2010) showing that the reduction potential in 2030 vary between 32-51%. Outcome from the analysis for the EU-15 (Ajanovic (2016)) shows 30% reduction potential up to 2030. In the paper where the period of analysis was the longest (der Zwaan (2013)) emissions in the EU-28 drop in 2100 three times comparing to the baseline. Results for Poland (Cambridge Econometrics (2018)) shows 50% reduction potential in the area of private cars and buses transport up to 2050.

37. To conclude, the subject of $CO_2$ emissions reduction from transport sector is being quite well documented but there are some difficulties concerning in-depth comparison between the outcomes of the papers. Nevertheless, there is still a great need of new scientific research in this area, mainly due to progressive changes in transport sector, new technologies development and changes of its costs as well as observed behavioral changes. Especially country specific analysis is crucial in order to catch national circumstances, what e.g. Polish share of second-hand cars import as a proportion of new registration, could have an important impact on the market development and $CO_2$ emissions in consequence(Cambridge Econometrics (2018)).

# 3. Model and data

## 3.1. TR³E model overview

38. The Transport European Emission Economic Model (TR³E) model is a simulation model, that shows the changes in transport activity, vehicle choice as well as modal choice and respective $CO_2$ emissions in relation to given baseline scenario. Furthermore, it allows for the detailed modelling of fleet dynamics by annual age cohorts, taking into account different scrappage rates by car generation, allows also for altering the average mileage and emission intensity by age. Model covers both passenger and freight transport. TR³E transport sector model is based on the concept of partial equilibrium. TR³E model consist of two main modules: passenger and freight. It covers four main areas of transportation: road, rail, aviation and inland and coastal shipping of goods in each of the European Union 28 Member States.

39. The construction of TR³E model is based on the notion that the transportation service by different modes are imperfect substitutes. Therefore, there is some cost, associated with switching from one transport mode to another. This choices are modelled using the common in economics CES (*Constant Elasticity of Substitution*) function. The derived demand function is as follows (see e.g. Rutherford(2002) for details):

$$Y_i = \theta_i Y \left(\frac{P_i}{P}\right)^{-\sigma}$$

Where $Y_i$ is the demand, $\theta_i$ is the baseline share of given mode, $P_i$ is price of the transportation using the given mode, $P$ is the price of the higher nest and $Y$ is the demand for total transportation service. Furthermore, $\sigma$ is the elasticity of substitution, showing the reaction of consumer to changes in the costs of transportation for the given mode. It is higher for e.g. trains and planes (as it is easier to switch between these two modes), than between public and private transport. CES function is used at the higher level of decision tree to determine the share of different modes (i.e. motorbikes, cars, buses, trains and aviation) in total passenger transport activity.

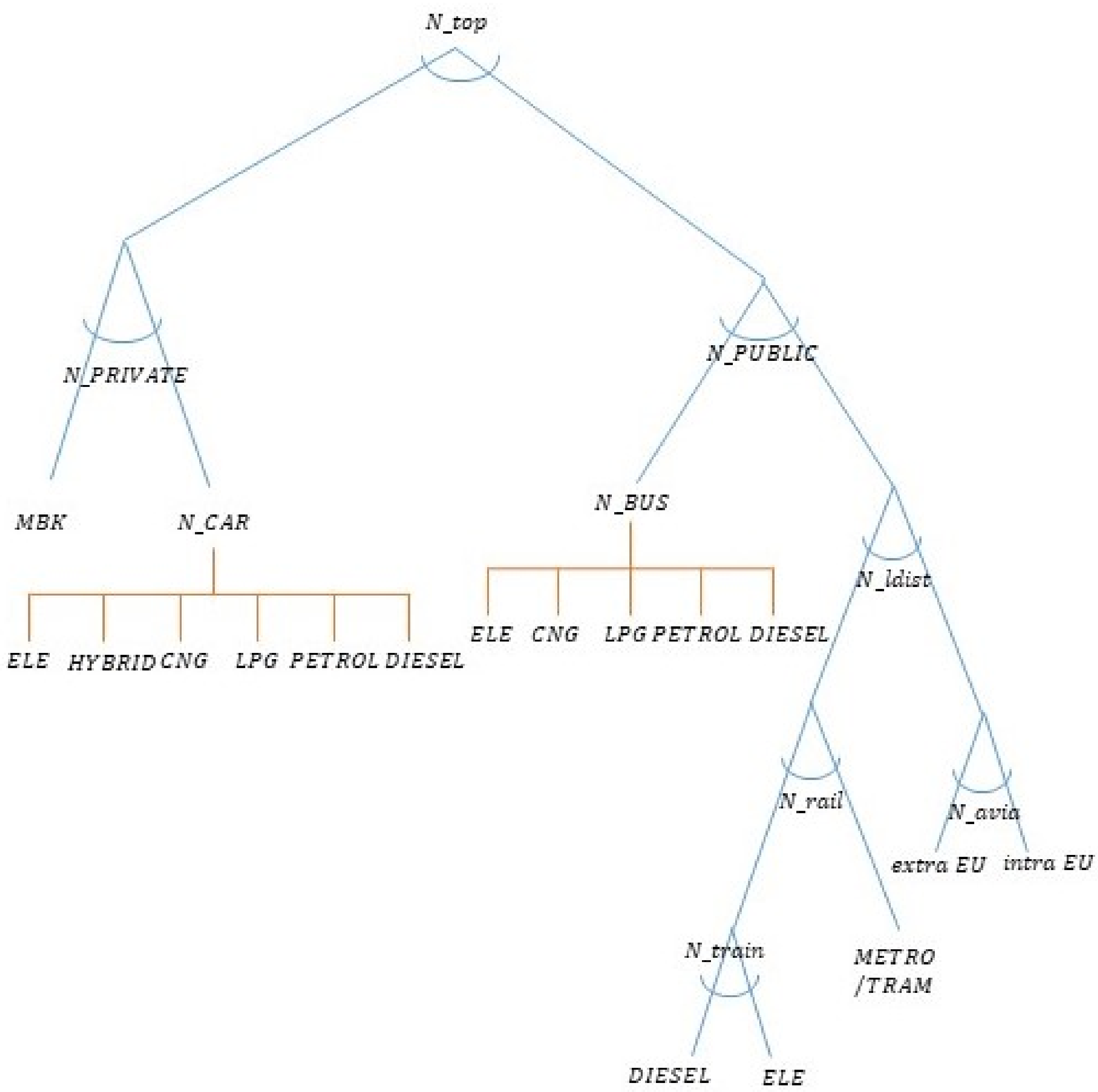
40. At the very basic level, cost per mile (CPM) concept is used for each mode. For motorbikes, cars and buses are three components of the cost per mile:

- cost of fuel (constant),
- cost of maintenance per each vehicle,
- cost of new vehicle.

41. Cost per mile can be disaggregated in the policy scenario (i.e. reduced cost of purchase a new vehicle due to government subsidies).

42. The choice of given vehicle (i.e. whether to use electric, hybrid, CNG, LPG, petrol or diesel car or bus) within the mode is the result of the existing fleet. Consequently, the transport needs within given mode are served proportionally to the vehicle fleet and costs vary accordingly.

**Figure 5. Decision tree for the passenger transport**




*Source: CAKE/KOBiZE own elaboration*

43. The fleet is modelled in the dynamic manner, using annual vehicle cohorts. Therefore, the number of vehicles within each type is the number of non-scrapped vehicles remained from the previous period plus the number of new vehicles

$$VEH_{i,t} = (1 - sc_{i,t})VEH_{i,t-1} + N\_VEH_{i,t}$$

44. The number of new vehicles within each type/technology is determined, according to the standard multinomial choice model and the share of the given technology in the sales of new vehicles is as follows:

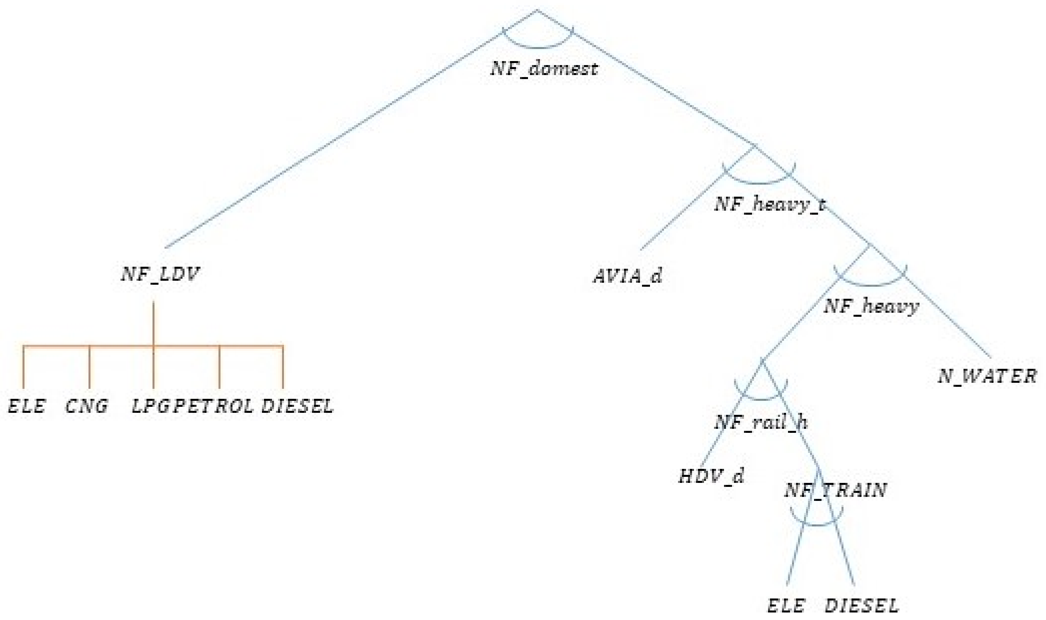
$$SHNV_{i,t} = \frac{\exp\left(\theta_{i,t}\left(\frac{CPM_{i,t}}{cpm_{i,t}}\right)^{-\sigma}\right)}{\sum_{j\in J}\exp\left(\theta_{j,t}\left(\frac{CPM_{j,t}}{cpm_{j,t}}\right)^{-\sigma}\right)}$$

45. Consequently, the share of given technology in new vehicle sales depends on the cost per mile, but the current use of technologies is determined by the existing fleet and cannot be changed.

46. The cost per mile for other means of passenger transport (i.e. train, metro and aeroplanes) is considered as a result of policy and is exogenous from the point of view of the model.

47. For freight transport, the logic is very similar, just other types of vehicles are modelled. Consequently, the decision tree for domestic freight transport is as follows:

**Figure 6. Decision tree for the domestic freight transport**

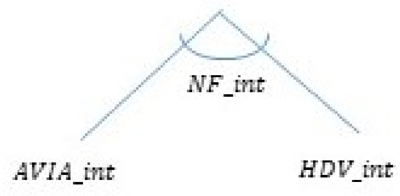



*Source: CAKE/KOBiZE own elaboration*

48. Consequently, the choice between aviation, rail, water and domestic HDV are modelled using the CES functions, while the demand for transportation services by different LDVs is determined by the fleet dynamics. The elasticity of substitution between LDVs and other part of freight decision tree is quite low, as LDVs are used rather for short distances within cities and the remaining means are used rather for long distances.

49. The decision tree for international freight transport is very simple as follows:

**Figure 7. Decision tree for the international freight transport**




*Source: CAKE/KOBiZE own elaboration*

50. Therefore, only the substitution between international HDV and freight aviation is modelled. Due to the unavailability of reliable data, our model does not contain international maritime transport.

## 3.2. Data

51. $TR^3E$ model is based on several data sources. The main data set comes from JRC IDEES database[15]. Integrated Database of the European Energy Sector (IDEES) brings together all statistical data that are relevant to the energy system, combining the energy balances with macro-economic, demographic, activity (e.g. industrial output; mobility) and climatic data. JRC-IDEES database contain historical statistical data concerning four main blocks: demographics, economy, activity levels and energy use. This data is complemented by sectoral detail as well as technology data and the operating characteristics. In JRC-IDEES detailed information about $CO_2$ emissions and stock energy equipment can be find.

52. JRC-IDEES database provides a very detailed decomposition of energy use and activity in transport sector for all EU member states. The structure of database was designed by representative "vehicle" configuration:

- Explicit techno-economic characteristics;
- Activity expressed in km driven;

[15] Mantzos L. et al, "JRC-IDEES: Integrated Database of the European Energy Sector - Methodological note", Publications Office of the European Union, Luxembourg, 2017

- Occupancy rate, vehicle's load factor.

53. Database covers 4 main transport modes (road, rail, aviation and water transport), up to 16 means of transport, as well as the characteristics on engine types (2-5) and technology options per mean (6-27). $TR^3E$ model is based on the IDEES data base version 1.0 which comprises observed data up to 2015.

54. Another source of model input data was the TRACCS database[16]. TRACCS was a project funded by European Commission (DG CLIMA) and its aim was the collection of transport data to support the quantitative analysis of measures relating to transport and climate change. In $TR^3E$ model TRACCS database was used as a source of costs data in transport sector. The database covers the years 2005-2010, and even that seems a little bit outdated it is the only coherent source of historic costs data for all EU member states. We derived from this database specific information on the costs of new vehicles, costs of maintenance and fuel costs. We used 2010 data as the most recent one of that dataset.

[16] G. Papadimitriou, "Transport data collection supporting the quantitative analysis of measures relating to transport and climate change: TRACCS", Final report, Emisia SA, 2013

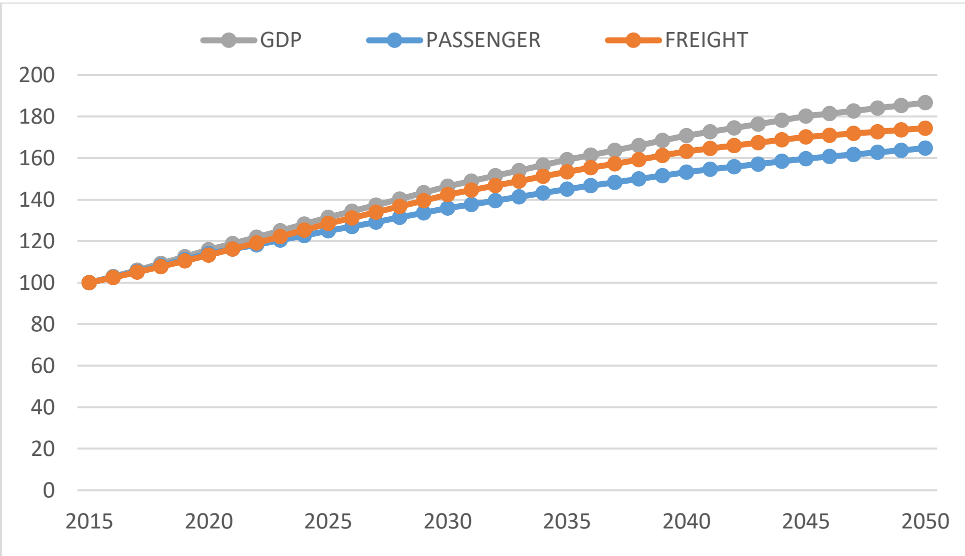
# 4. Baseline scenario

## 4.1. Overall changes in activity

55. In TR³E model the baseline scenario is prepared to better understand the impact of the implementation of current policies and measures on the sector activity as well as on the $CO_2$ emissions levels. Baseline scenario serves as a reference point to which comparison of analytical (policy) scenarios is made.

56. In the baseline scenario, we set different assumptions on the development of the economy and specific indicators as $CO_2$ emissions intensity, the prices of different types of vehicles and costs of fuels. We adopt the same activity growth projections both for baseline scenario and for analytical (policy) scenarios. Activity growth assumed in the model is consistent with the Reference Scenario of PRIMES model[17]. Therefore, in the case of Poland average GDP growth between 2015 and 2050 is set to 1.8% (y/y), while the average growth in activity is set to 1.4% y/y for passenger and 1.6% y/y for freight transport. For the EU average growth in activity between 2015 and 2050 has been set to 0.9% for passenger and 1.4% for freight respectively (y/y). Emission intensities in the baseline scenario are set at the same level as in the EU Reference Scenario 2016.

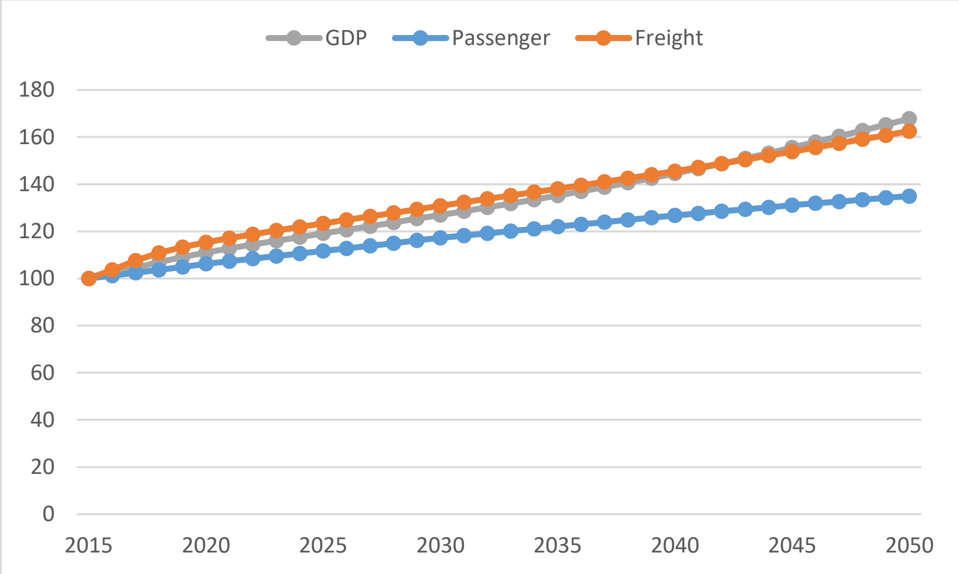
**Figure 8. Growth in passenger and freight activity in Poland (%)**




*Source: TR³E model*

[17] "EU Reference Scenario 2016. Energy, transport and GHG emissions Trends to 2050", European Commission 2016

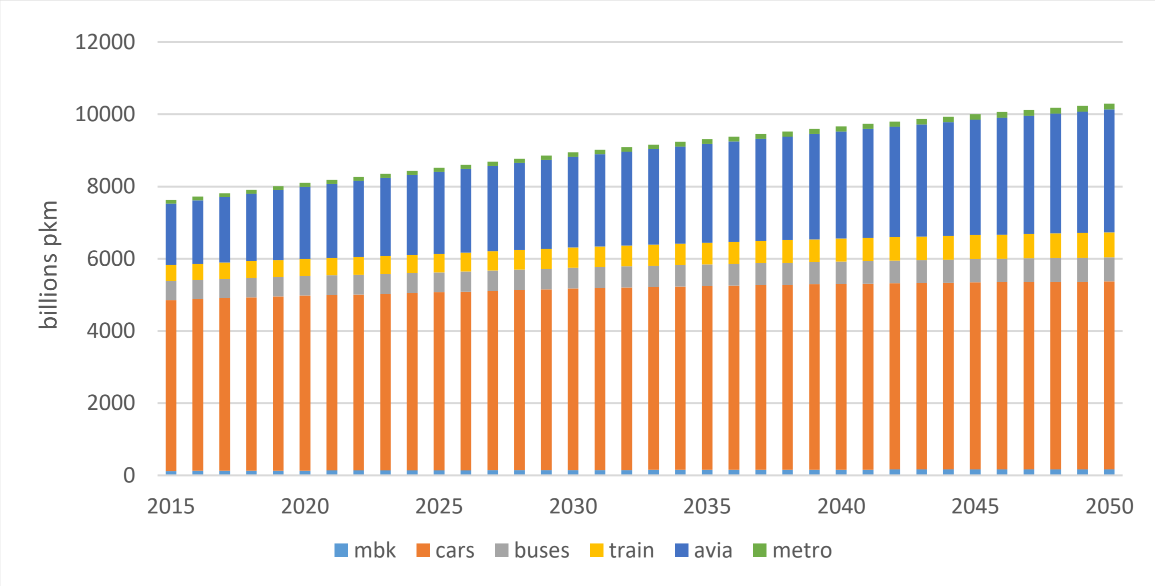
### Figure 9. Growth in passenger and freight activity in EU (%)




*Source: TR[3]E model*

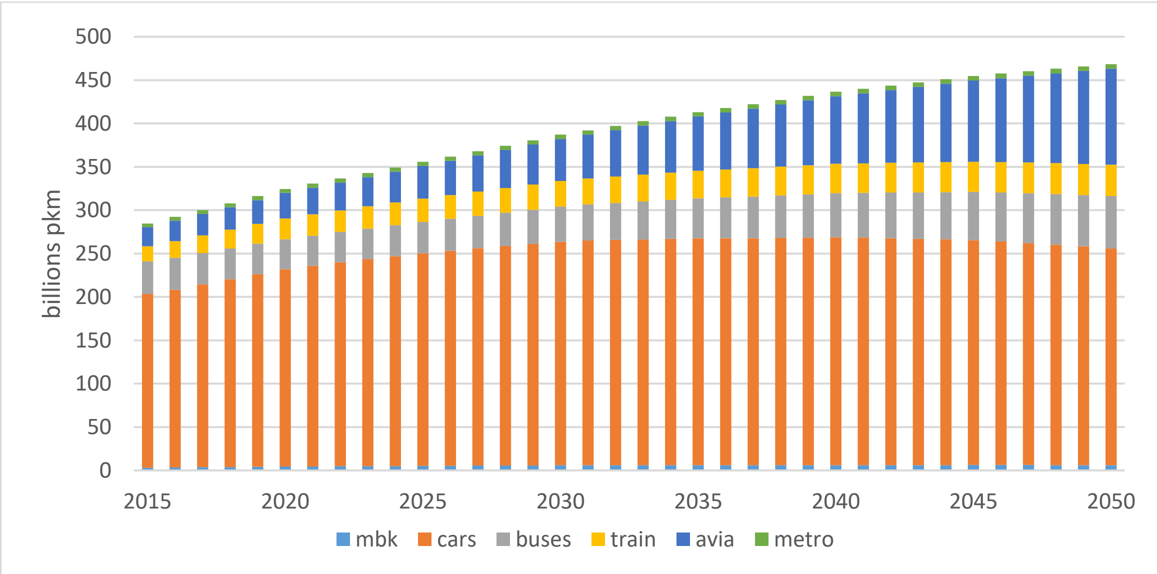
57. Private cars represent more than a half of total passenger transport activity in the EU (however, this share will fall from 62% in 2015 to 51% in 2050). Second largest mode of passenger transport is aviation with a growth in share from 22% in 2015 to 33% in 2050. Such change is fueled by the GDP and welfare growth – wealthier passenger choose to commute using more convenient and faster air transport over other modes. In case of Poland, share of private cars activity in passenger transport is higher than in the EU, but it falls from 70% (in 2015) to 53% (in 2050). The growth in the share of aviation in passenger transport in Poland will be substantial – from 8% in 2015 to 24% for 2050. Such change is motivated by the convergence of the Polish transport patterns to that observed in other EU member states as well as by the economic development and increase in wealth.

## Figure 10. Passenger transport activity in EU (billions pkm)




*Source: TR³E model*

## Figure 11. Passenger transport activity in Poland (billions pkm)



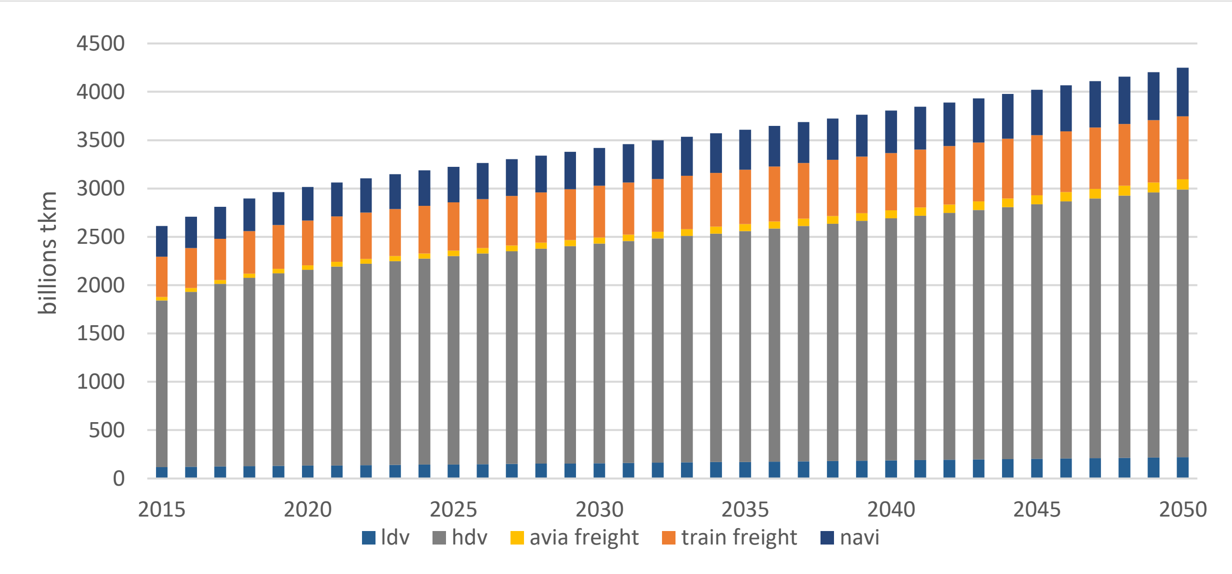

*Source: TR³E model*

58. Aviation is the most growing part of transport sector in Poland and projected activity in 2050 is five times higher than in 2015. In the EU, the growth is slightly slower and activity in 2050 is almost two times higher than in 2015. In case of buses the EU activity in 2050 will grow about 20%, while in Poland, we expect 60% growth between 2015 and 2050. In the baseline scenario, we expect 10-20% growth (depending on the

country) in the number of passenger-kilometers travelled by cars between 2015 and 2050.

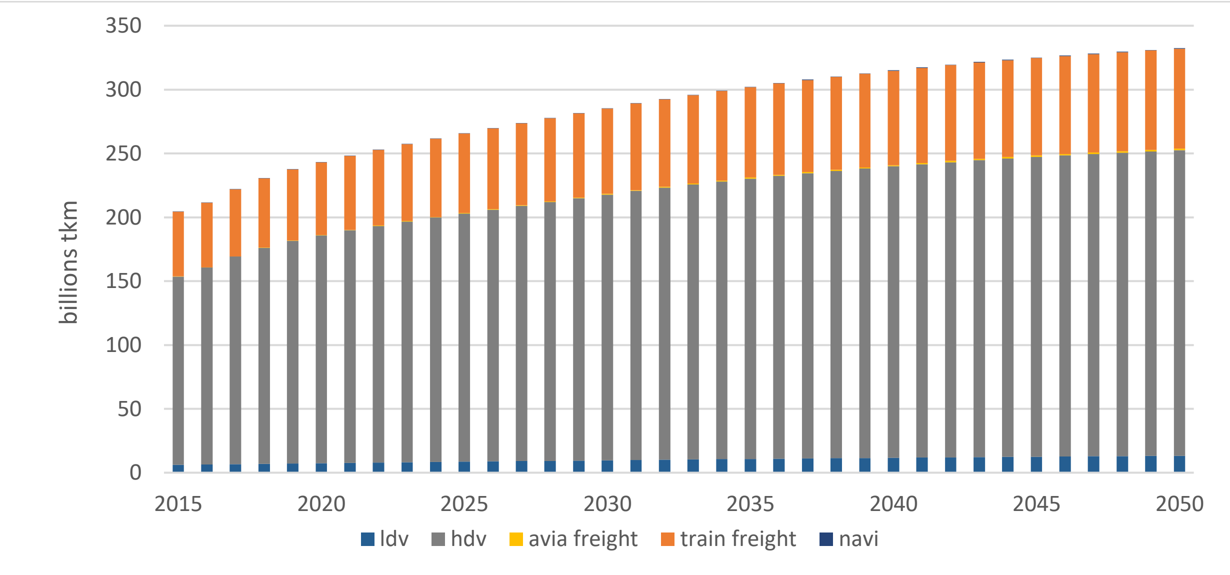
59. It is worth to mention that freight transport relies mainly on heavy duty vehicles. Share of that activity in total freight transport remains constant between 2015 and 2050 - 64% in the EU and 72% in Poland.

**Figure 12. Freight transport activity in EU (billions tkm)**




*Source: TR³E model*

**Figure 13. Freight transport activity in Poland (billions tkm)**



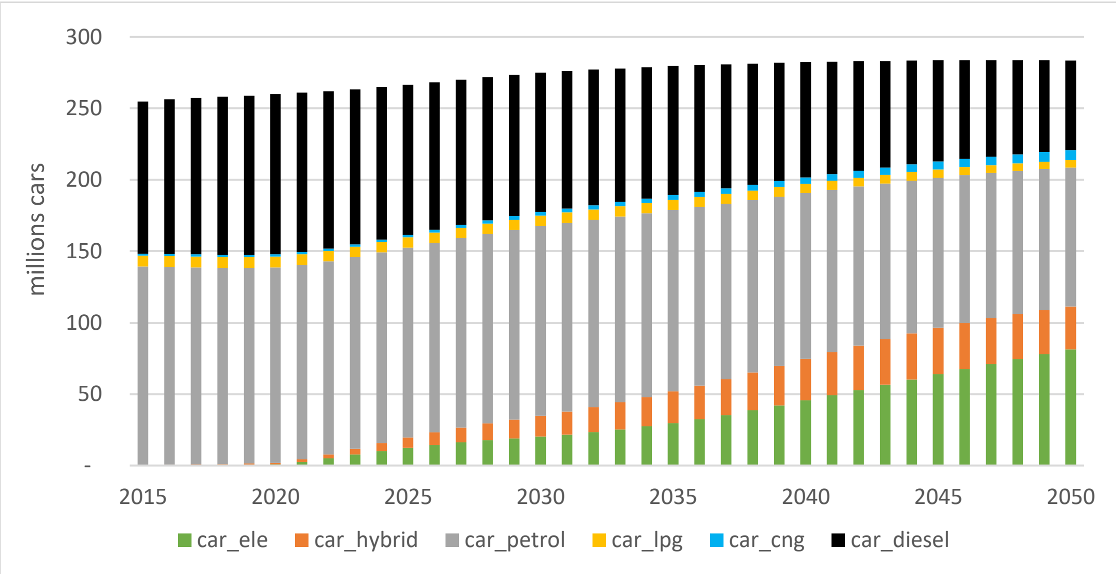

*Source: TR³E model*

## 4.2. Fleet dynamics

60. Fleet of private cars in the EU-28 in 2015 consisted mostly of petrol (55%) and diesel cars (42%). After 2020 growth in electric cars fleet is assumed. In the baseline scenario, in 2050 the share of EVs in total passenger cars fleet will constitute 29% of total, while share of petrol and diesel cars will decrease to 34% and 22% respectively.

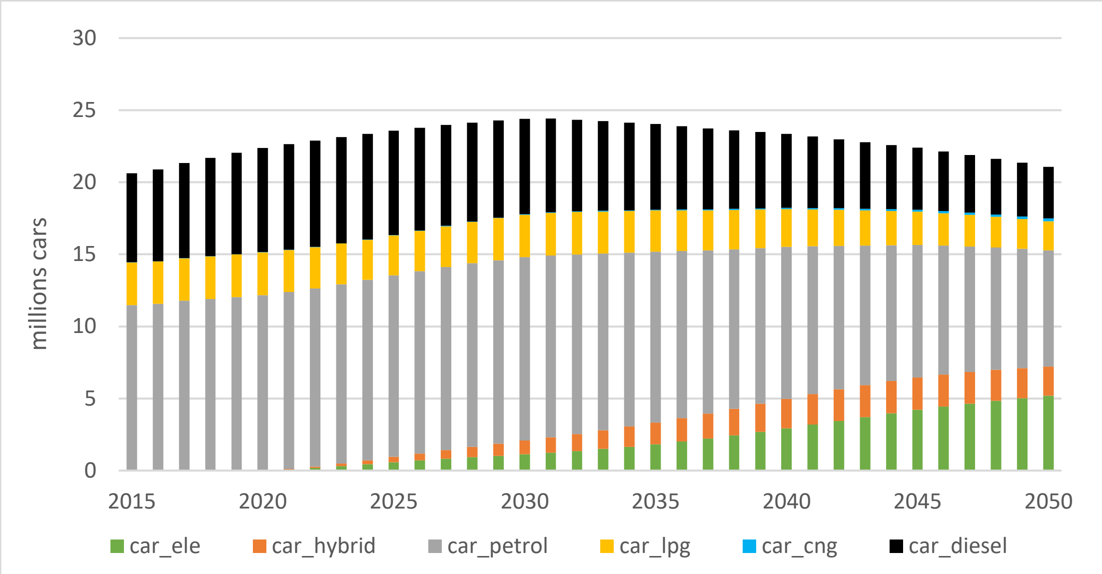
61. Similar trends will be observed in Poland. In 2015, the share of petrol cars is 56% and diesel cars is at 30% (% of total cars). In baseline scenario the share for electric cars is assumed in 2050 at the level of 25%, which is 5 p.p. below the EU-28 average. The share of hybrid vehicles is assumed to grow to 11%. As a consequence of transport electrification, in 2050 the share of petrol cars will decrease to 38% and of diesel cars to 17%.

**Figure 14. Number of passenger cars in EU (millions)**




*Source: TR³E model*

**Figure 15. Number of passenger cars in Poland (millions)**

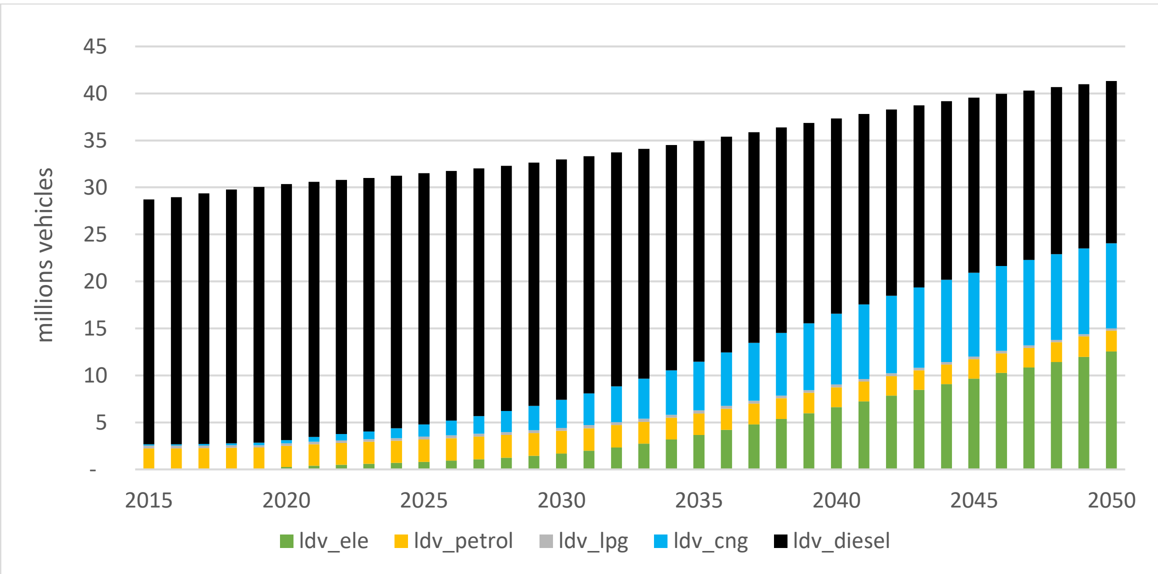



*Source: TR³E model*

62. As it comes to freight fleet, baseline scenario results show the increase in the EU of total number of vehicles in freight transport between 2015–2050. Average growth rate is at 1,1% (y/y). It is assumed that in 2050 share of electric light duty vehicles in EU will reach 29%.

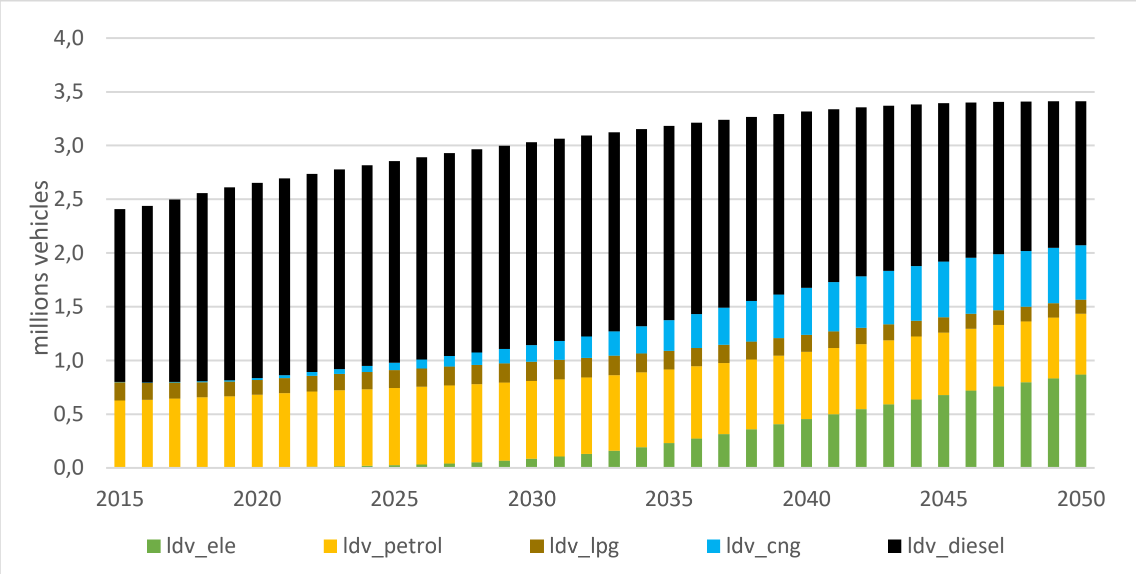
63. Baseline scenario results shows that in Poland numbers of LDV and HDV will growth in the rate 0,7% y/y (0,4p.p. lower than in EU). The share of electricity LDV in 2050 will be on level about 25%.

**Figure 16. Freight (LDV) transport fleet in 2015-2050 in EU (millions)**




*Source: TR³E model*

**Figure 17. Freight (LDV) transport fleet in 2015-2050 in Poland (millions)**



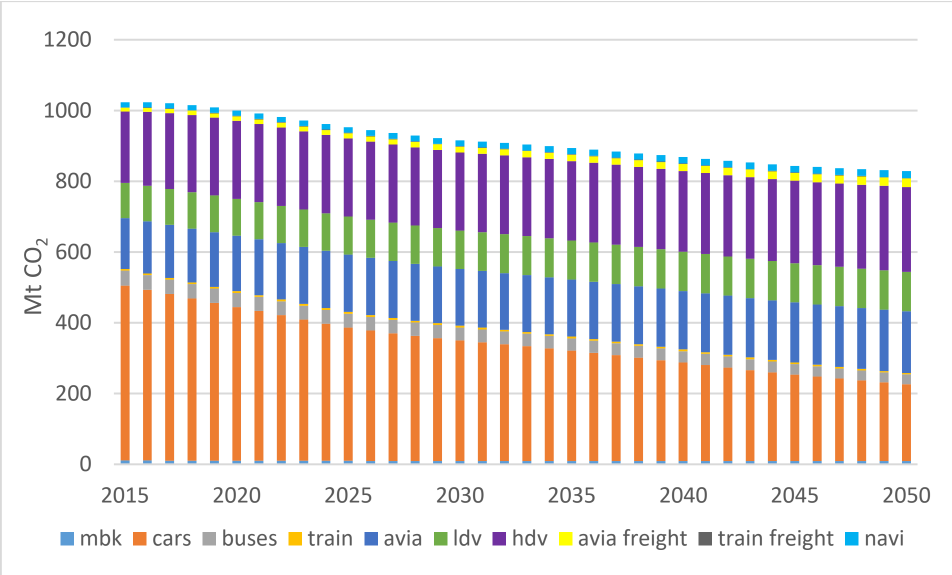

*Source: TR³E model*

64. In the period 2015-2050, both in the EU and in Poland the dominant share of diesel light duty vehicles in the total number of vehicles is worth to underline (39% in Poland and 42% in the EU in 2050).

## 4.3. $CO_2$ emissions – reduction potential

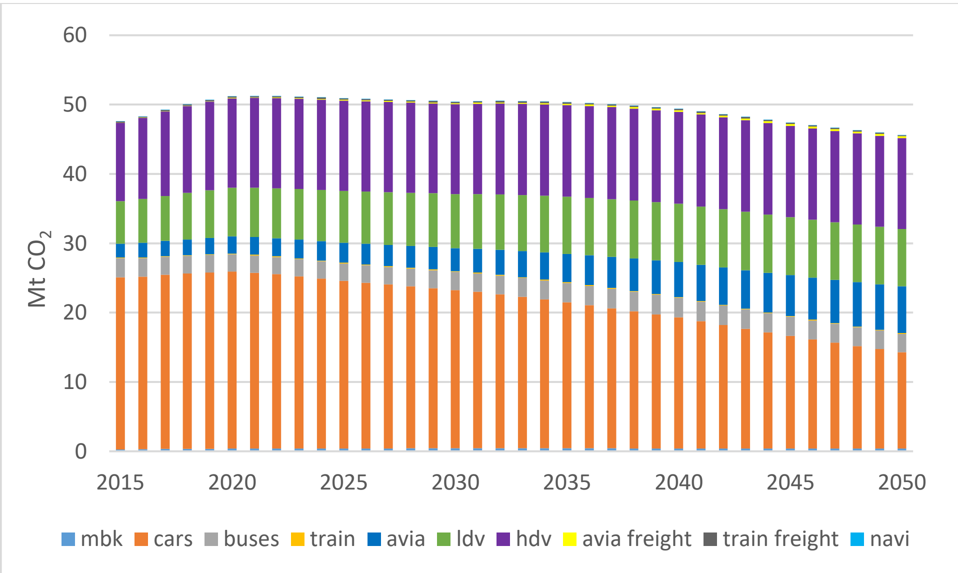
65. In baseline scenario in EU we can observe three main factors contributing to the $CO_2$ emissions: private cars transport (share of 48% in 2015 and 26% in 2050), passenger aviation (share of 14% in 2015 and 21% in 2050) and heavy duty vehicle transport (share of 20% in 2015 and 29% in 2050). In Poland the situation in terms of the emissions from transport sector is similar to the one in the EU but has a slightly different shares. Emissions from cars are at the level of 52% in 2015 and 30% in 2050, emissions of light duty vehicles – 13% in 2015 and 18% in 2050. In case of heavy duty vehicles we observe higher shares for Poland than in the EU average - 24% in 2015 and 29% in 2050. Passenger aviation has lower share than in the EU – about 15%.

### Figure 18. $CO_2$ emissions by mode in 2015-2050 in EU (Mt $CO_2$)




Source: *TR³E model*

### Figure 19. $CO_2$ emissions by mode in 2015-2050 in Poland (Mt $CO_2$)




Source: *TR³E model*

66. Difference between EU and Poland is the distribution of emissions over time. In the EU we observe constant decrease of total emissions from the 2015. In case of Poland starting from the 2015 emissions are rising reaching the maximum level in the 2021 and then we can observe slightly decrease until the end of analysed period of time.

67. In Poland $CO_2$ emissions reduction in 2050 vs 2015 is -4% (45.6 Mt in 2050). In the EU $CO_2$ emission reduction of is much deeper than in Poland -19% in 2050 vs 2015 (829 Mt $CO_2$).

# 5. Analytical scenarios

68. Four different analytical scenarios were prepared to assess possible impact of new technologies development in the transport sector on total sector activity, $CO_2$ emissions and energy needs. It is important to underline that our analysis focused on private cars and LDVs as the main drivers of emissions reduction in transport sector. Technology changes in the field of HDVs, railway are only modelled via emissions intensity improvements.
We do not assume green technologies development for HDVs. Three technology progress scenarios (Low, Moderate and High) and one Forced electromobility scenario were prepared. The common features of analytical scenarios are shown in table 2.

**Table 2. Common provisions for the analytical scenarios**

| | Description: |
|---|---|
| All scenarios | • Assumed emissions intensity improvement both for passenger and for freight transport;<br>• Growth of costs for users in case of aviation and decline of this costs for train transport. |

*Source: CAKE/KOBiZE own presentation*

69. The features which are specific for every scenario are in the table 3.

**Table 3. Description of analytical scenarios**

| Name: | | Description: |
|---|---|---|
| Technology progress scenario | Low | • Significant consumer resistance to switch towards electric vehicles;<br>• Possible limitations in infrastructure development (charging points);<br>• Vehicle prices are not the main incentive for consumers;<br>• In the EU, share of electric cars and LDVs in total fleet in 2050 are at the levels of 44% and 42% respectively;<br>• Total $CO_2$ emissions reduction at 45% versus 2015 level. |
| | Moderate | • Consumers behavior is less resistant, and more open for new technologies;<br>• Infrastructure does not limit the development of the EVs fleet<br>• In the EU electric cars and LDVs in total fleet in 2050 are at the level of 52% and 46% respectively;<br>• Total $CO_2$ emissions reduction at 47% from 2015 level. |
| | High | • Same assumpitions as in moderate scenario but with additional incentives for EVs penetration (e.g. more convenient charging technologies);<br>• In the EU electric cars and LDVs in total fleet in 2050 are at the level of 64% and 53% respectivelyTotal $CO_2$ emissions reduction at 52% from 2015 level. |
| **Forced electro-mobility scenario** | | • Change in prices of aviation transport to limit activity;<br>• No additional changes in electric vehicles prices nor operational costs;<br>• Highershare of hybrid cars at the level of 15%;<br>• No new ICE cars on the market from 2045;<br>• In the EU electric cars and LDVs are at the level of 82% and 96% respectively in 2050; Emissions intensity improvement both for passenger and for freight transport;<br>• Total $CO_2$ emissions reduction at 67% from 2015 level (the rest of emission in aviation and HDV sectors). |

*Source: CAKE/KOBiZE own presentation*

## 5.1. Assumptions in analytical scenarios

70. Analytical scenarios are based on several assumptions. These assumptions can be grouped into four different areas:

- Change of vehicle prices up to 2050,
- Change of aviation`s and train`s costs per mile,
- Growth in average mileage for fleet,
- Improvement of emissions intensity.

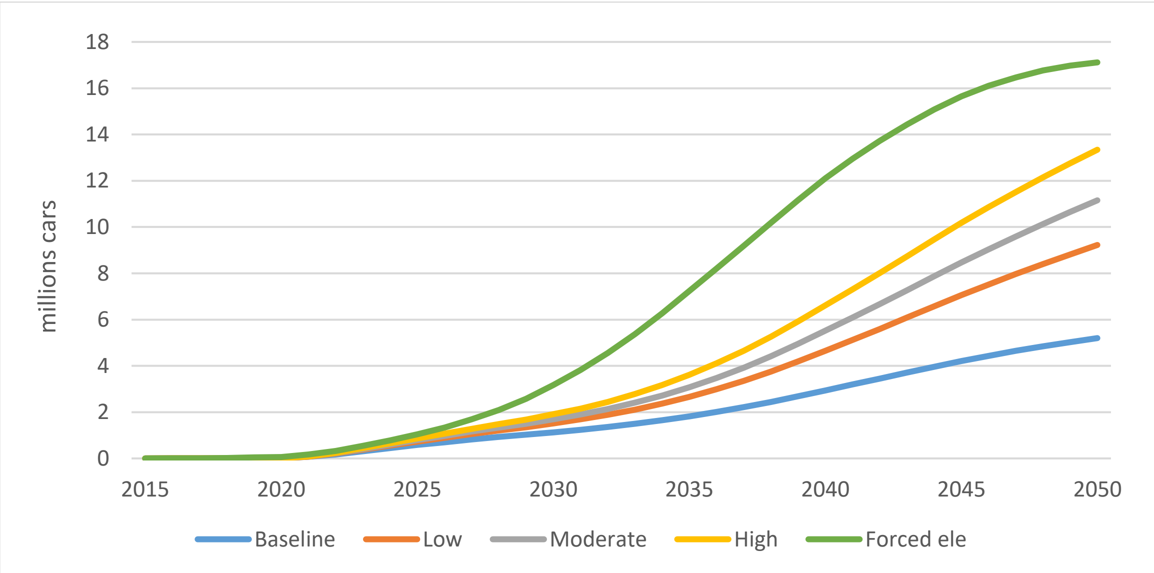
71. These four model “shocks” are responsible (all together) for emissions reduction ranging from 33% to 56% $CO_2$ in Poland (depending on the analytical scenario) and from 43% to 58% in EU. Detailed results of $CO_2$ emission change are presented in section 7.4.

### 5.1.1. New vehicles prices change in time

72. The change of the consumers behavior due to vehicle prices development in the future is one of a key drivers of analytical scenarios. We assumed changes in prices of new vehicles up to 2050. For passenger transport we set between 1% and 1.5% price fall year to year for electric and hybrid cars. Prices of light duty vehicles for technologies based on fossil fuels consumption are 0.5% higher year to year than in the baseline assumptions. In case of electric light duty vehicle we assumed 0.5% year by year new vehicle prices fall in comparison to the baseline prices. Prices of electric buses are supposed to decrease by 2% year by year. These assumptions are valid both for the EU and for Poland.

73. Electric cars activity is one of the most important indicator for the comparison between analytical scenarios and the baseline. Scenarios results show more than a triple higher growth of electric cars number in the EU comparing to the baseline (case of Forced electromobility scenario -figure 20). In case of Low, Moderate and High scenarios number of electric vehicles in Poland is growing in a stable way. Results for Forced electromobility scenario shows that around 2045, a sort of market saturation can be observed and the rate of growth of electric cars is falling.

**Figure 20. Number of electric cars in Poland (millions)**




*Source: TR³E model*

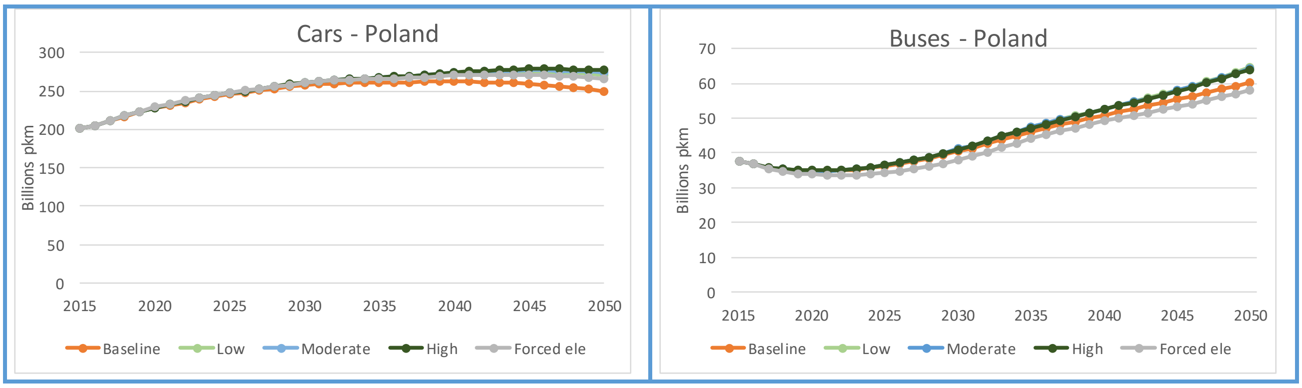
### 5.1.2. Aviation and rail transport activity shift

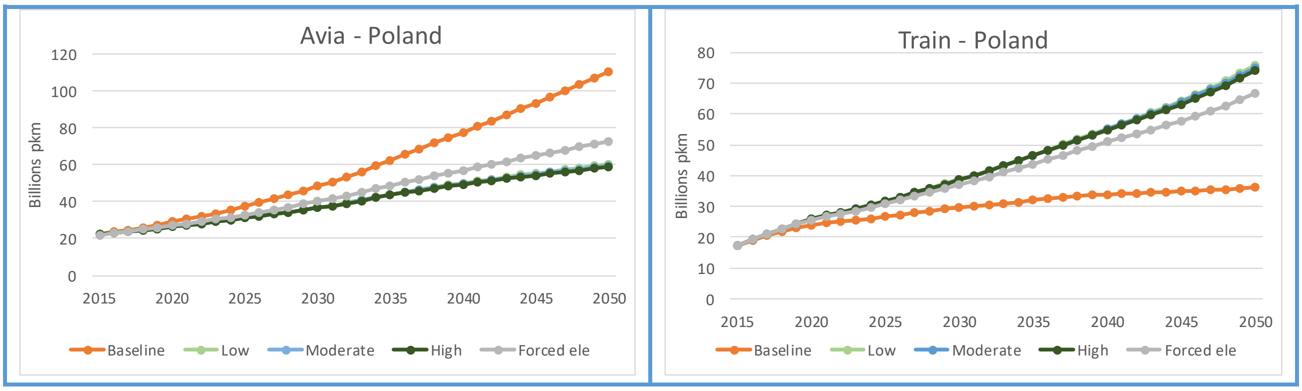
74. Second area of change in analytical scenario comparing to the baseline scenario is the aviation sector. As aviation represents important $CO_2$ emissions rise due to activity growth, we have assumed 1% yearly growth of costs per mile in that sector, what will have an impact on consumer decision. In a given period of time 2015-2050 it will cause over 40% price rise for customers, and it will have an important impact on the activity. From the other hand the promotion of rail transport is assumed as well the gradual decline of cost per mile in case of railway transport (0.25% y/y for trains).

75. One of the main conclusions is that the increase of prices in aviation sector will decrease the demand and the activity in 2050 by more than a half in comparison to the baseline. The level of activity within whole transport sector will be maintained. This important change will be done mostly by consumers switching from planes to trains mainly and to cars and buses in the second order – see figure 21.

76. Increased prices for consumers of aviation activity with simultaneous decrease of costs for train users, has visible impact on the remaining passenger transport activity. In case of passenger cars transport - this impact is limited and starts being recognizable after the year 2040. When it comes to public buses transportation, impact of growing costs in aviation is clearly visible starting from 2020 and remains equal for all analysed scenarios. Undoubtedly, growing costs per user for aviation transport, have limited the activity in that sector in all scenarios. Opposite impact is seen in train transport, as lower prices influenced consumers decisions to use this mean of transport in the more common way. Results of analytical scenarios show more than a double increase of activity (in Forced electrification scenario this growth is slightly smaller).

**Figure 21. Comparison of baseline and scenarios passengers transport activity results for Poland (billions pkm)**






*Source: TR³E model*

### 5.1.3. Growth in average mileage

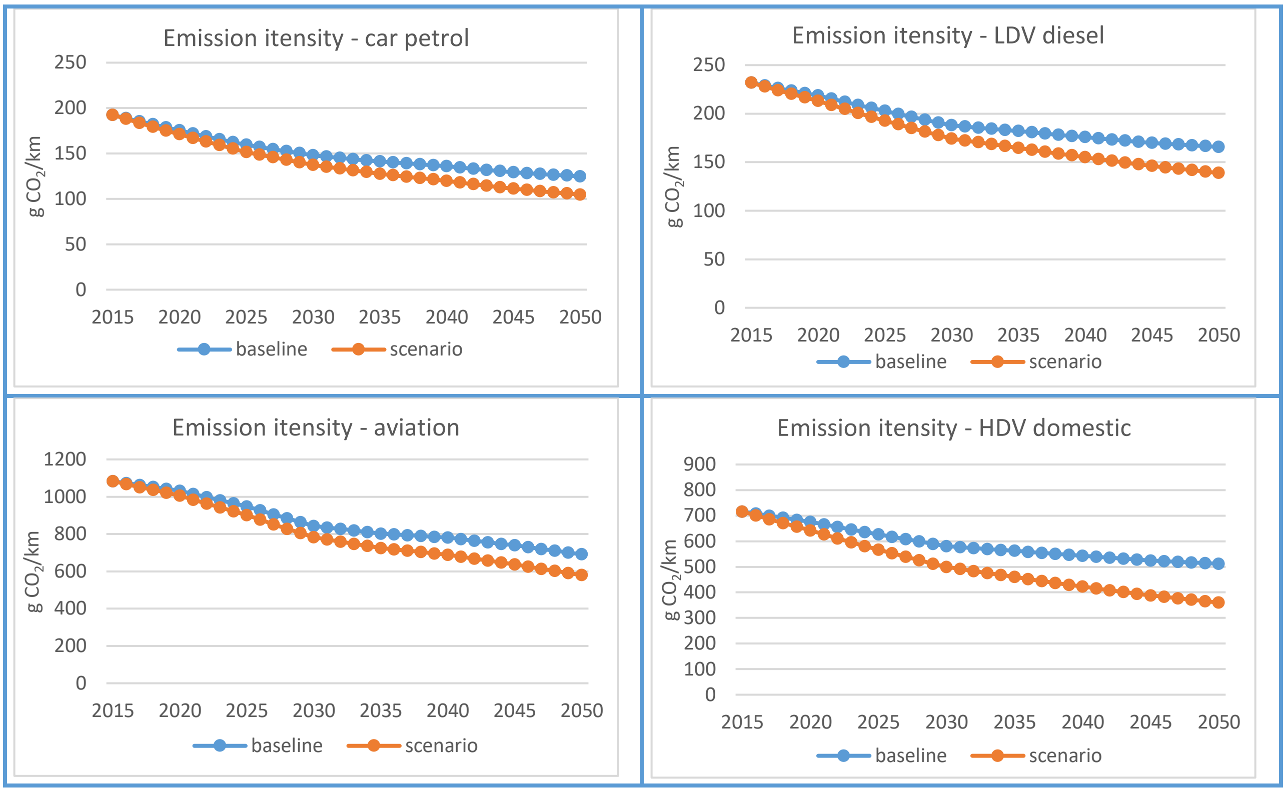
77. Next model shock is linked to the assumed growth of average mileage. For Poland we set up a steady growth between 0.5-2.0% for passenger cars fleet, motorbikes, LDVs and HDVs mileage. In case of EU growth in mileage is assumed only for LDVs at the level of 1.5%.

78. Growth in mileage is linked to the GDP growth and the further development of the transport infrastructure. Growth of mileage is in correlation with growing activity in transport sector and the changes in users behavior. Fastest and newest vehicles and also modern infrastructure allow users to travel at the longer distances in more efficient way. For the EU we made an assumption that for the fleet of cars, motorbikes and HDVs the growth rate of average millage remains at a baseline level. It can be justified by average better development of infrastructure than in Poland and lower GPD growth. As well the growth of passenger transport activity in the EU is lower comparing to Poland.

### 5.1.4. Emission intensity improvement

79. The third change foreseen in the analytical scenarios is linked to the $CO_2$ emissions intensity development due to the technology progress. We have assumed the improvement of the emissions intensity in analytical scenarios as compared to the baseline. We presume that for private cars, public passenger road transport, LDV and aviation transport the improvement of emissions intensity will be at the same level of 0.5% annually, both for the EU 28 and for Poland (16% reduction in scenario vs baseline in 2050). This emission intensity improvement will be done by the implementation of new emissions targets and fuel quality measures. In case of HDV and water transport (freight), we assumed higher improvement of emissions intensity (1.0% yearly vs baseline), mainly due specific policies in that area and the progress in improving emission efficiency of HDVs.

## Figure 22. Emission intensity changes in baseline vs analytical scenarios in EU and Poland (g $CO_2$/km)




*Source: TR³E model*

# 6. Results

## 6.1. Overview of results - Poland

80. Results for Poland shows substantial potential in $CO_2$ emissions reduction for cars and LDVs. In technology progress scenarios (Low – Moderate – High) the deployment of electric vehicles (LDVs and cars) is on the same level meanwhile in Forced electromobility scenario the share of LDVs vehicles is nearly 100%. LDVs activity in comparison to cars is growing faster in the baseline scenario what is visible in $CO_2$ emissions levels, assuming the same share of electric technology penetration. This is due to the relative costs – cheaper electric vehicles will lure customers to that kind of transport from other modes, like HDVs in case of freight and trains and buses in case of passenger transport. In the baseline $CO_2$ emissions in LDVs will be 35% higher than in 2050 comparing to 2015. In case of cars we assume visible emissions fall by 44%.

**Table 4. Results overview for Poland for 2050**

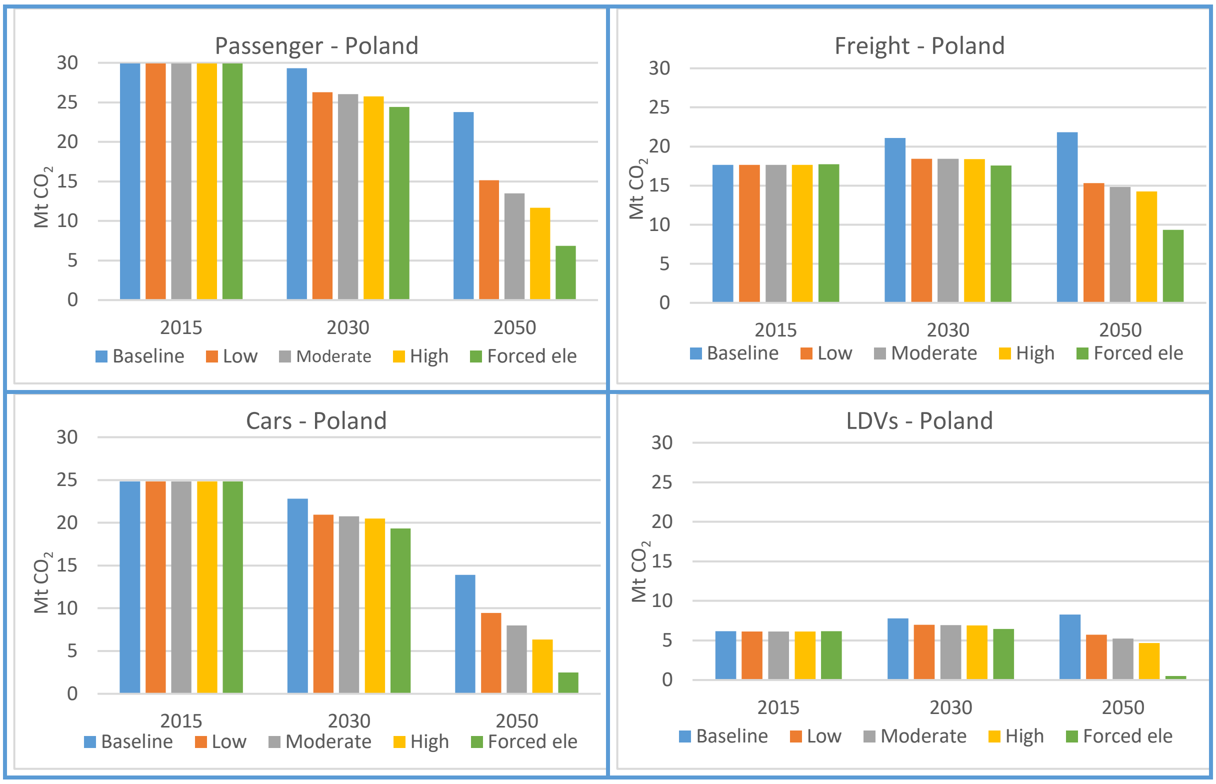
| | Baseline | Low | Moderate | High | Forced electromobility |
|---|---|---|---|---|---|
| **% of electric cars in 2050** | 24% | 39% | 47% | 57% | 80% |
| **% of electric LDV`s in 2050** | 25% | 40% | 46% | 54% | 96% |
| **$CO_2$ reduction – cars (2050/2015)** | -44% | -62% | -68% | -74% | -90% |
| **$CO_2$ reduction - LDVs (2050/2015)** | +35% | -7% | -14% | -24% | -92% |
| **$CO_2$ reduction - total (2050/2015)** | **-4%** | **-36%** | **-40%** | **-45%** | **-66%** |
| **$CO_2$ emissions in 2050 (Mt)** | **47.5** | **30.5** | **28.5** | **26.0** | **16.2** |

*Source: CAKE/KOBiZE own presentation*

81. Comparing $CO_2$ emissions in passenger transport and in freight in Poland, one crucial difference should be underlined. In case of passenger transport the $CO_2$ emissions are projected to decline between 2015 and 2050 in the baseline scenario. In freight transport in baseline we assume growth of $CO_2$ emissions up to 2050, due to little penetration of new low emissions technologies and a growth of total freight activity driven by the economic growth. Most of the reduction will take place after 2030,

following fleet replacement caused by gradual fall of electric vehicles prices and favorable policy implementation.

**Figure 23. $CO_2$ emissions in Poland (Mt $CO_2$)**




*Source: TR³E model*

## 6.2. Overview of results – EU

82. The share of electric cars in the EU in 2050 is between 44% - 64% (in Low – High scenarios) and at 82% level in Forced electromobility scenario. It caused $CO_2$ emissions reduction from 70% in Low to 82% in High and 94% in Forced electromobility scenario.

83. If we have a look on the share of LDVs vehicles in the EU, we can observe small increase of this share between Low – High scenarios towards 2050 (11 p.p. differences). In the Forced electromobility scenario the share of electric LDVs is much higher, reaching almost 100% in 2050. The emissions reduction in Forced electromobility scenario for LDVs is at 93% level in 2050 comparing to the 2015.

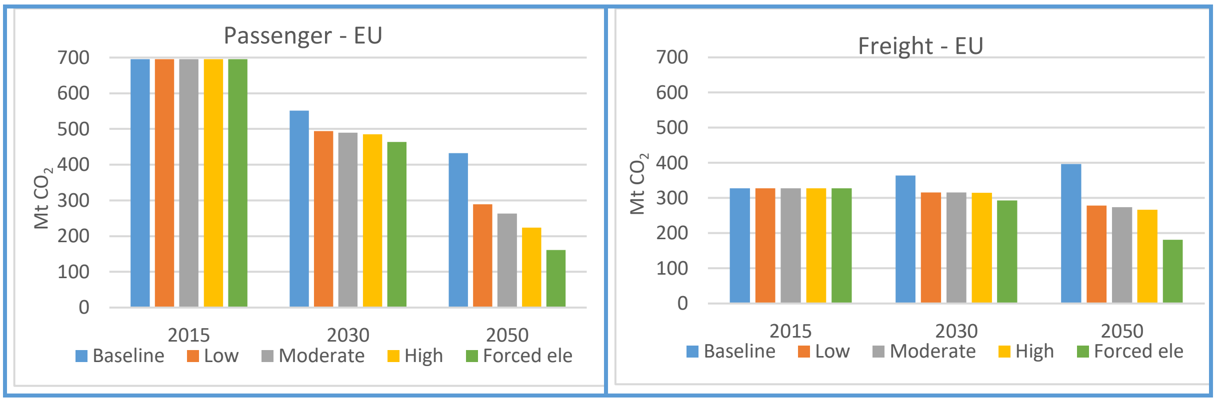
### Table 5. Results overview for the EU for 2050

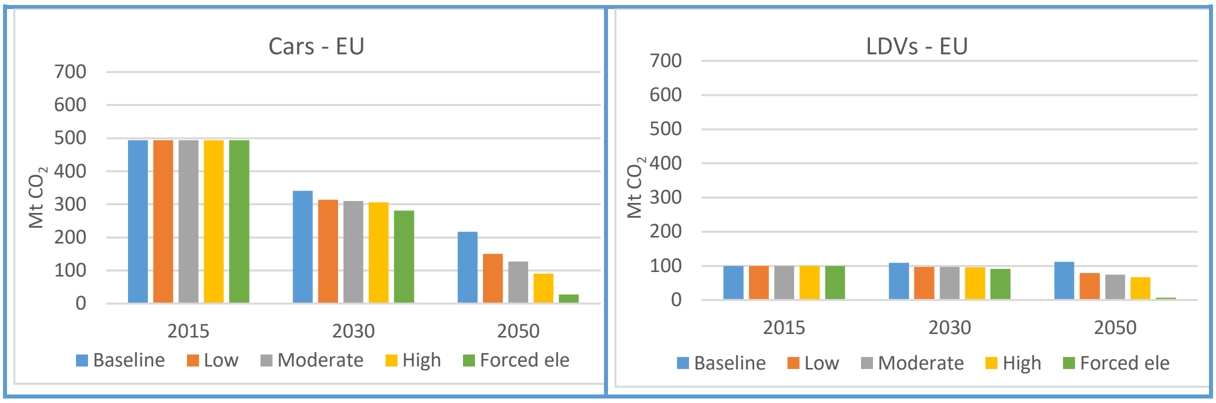
| | Baseline | Low | Moderate | High | Forced electromobility |
|---|---|---|---|---|---|
| % of electric cars in 2050 | 29% | 44% | 52% | 64% | 82% |
| % of electric LDV`s in 2050 | 30% | 42% | 46% | 53% | 96% |
| $CO_2$ reduction – cars (2050/2015) | -56% | -70% | -74% | -82% | -94% |
| $CO_2$ reduction - LDVs (2050/2015) | +12% | -21% | -26% | -33% | -93% |
| **$CO_2$ reduction - total (2050/2015)** | **-19%** | **-45%** | **-47%** | **-52%** | **-67%** |
| **$CO_2$ emissions in 2050 (mln of tonnes)** | **829** | **568** | **537** | **491** | **342** |

*Source: CAKE/KOBiZE own presentation*

84. From the $CO_2$ emissions point of view, it is important to mention that both cars in passenger transport, and LDVs in freight transport are the important areas of emissions reductions. In the baseline cars are responsible for more than 70% of the emissions in 2015, and less than 50% in 2050. The major reductions occur after 2030, what is driven by a fall of new technologies prices and specific policy circumstances.

### Figure 24. $CO_2$ emissions in EU (Mt $CO_2$)



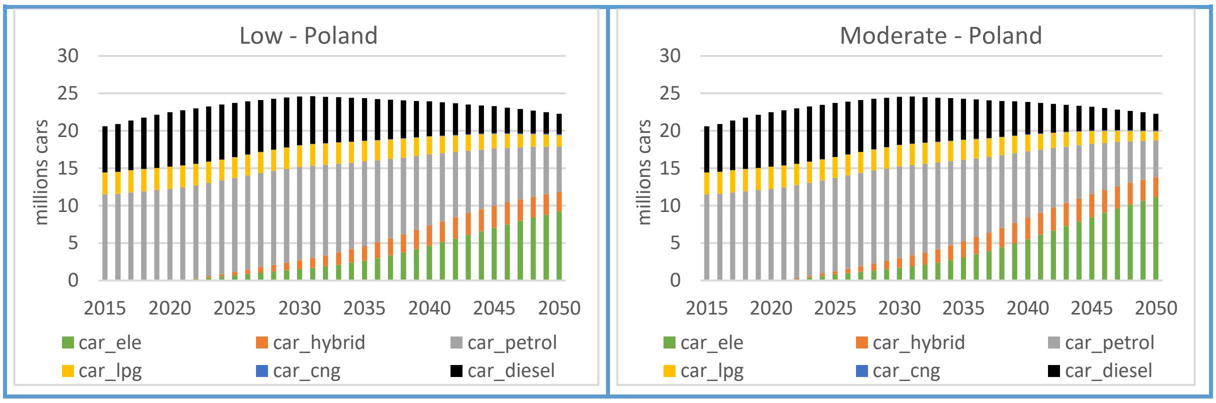


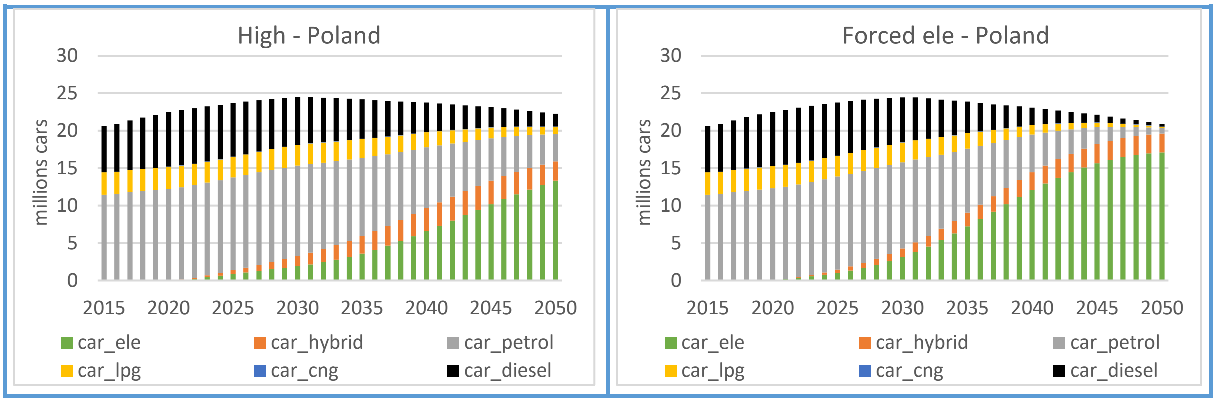

*Source: TR³E model*

## 6.3. Changing the structure of cars and LDVs

85. Two main conclusions can be drawn from the scenario analysis. If it comes to the structure of cars fleet in Poland Low, Moderate and High scenarios has comparable impact on the number of vehicles, and the total number of vehicles reaches 22.3 mln in 2050. Contrary to this three scenarios, in forced electromobility scenario total number of cars is relatively smaller and in 2050 is close to 21 mln. The biggest share of EVs is foreseen in Forced electromobility scenario. The share of hybrid engine cars in 2050 is on the same level in all scenarios – 12%. In Forced electromobility scenario the total number of electric vehicles is at level – 17mln, meanwhile in High at level 13 mln.

**Figure 25. Structure of cars fleet in Poland (millions)**

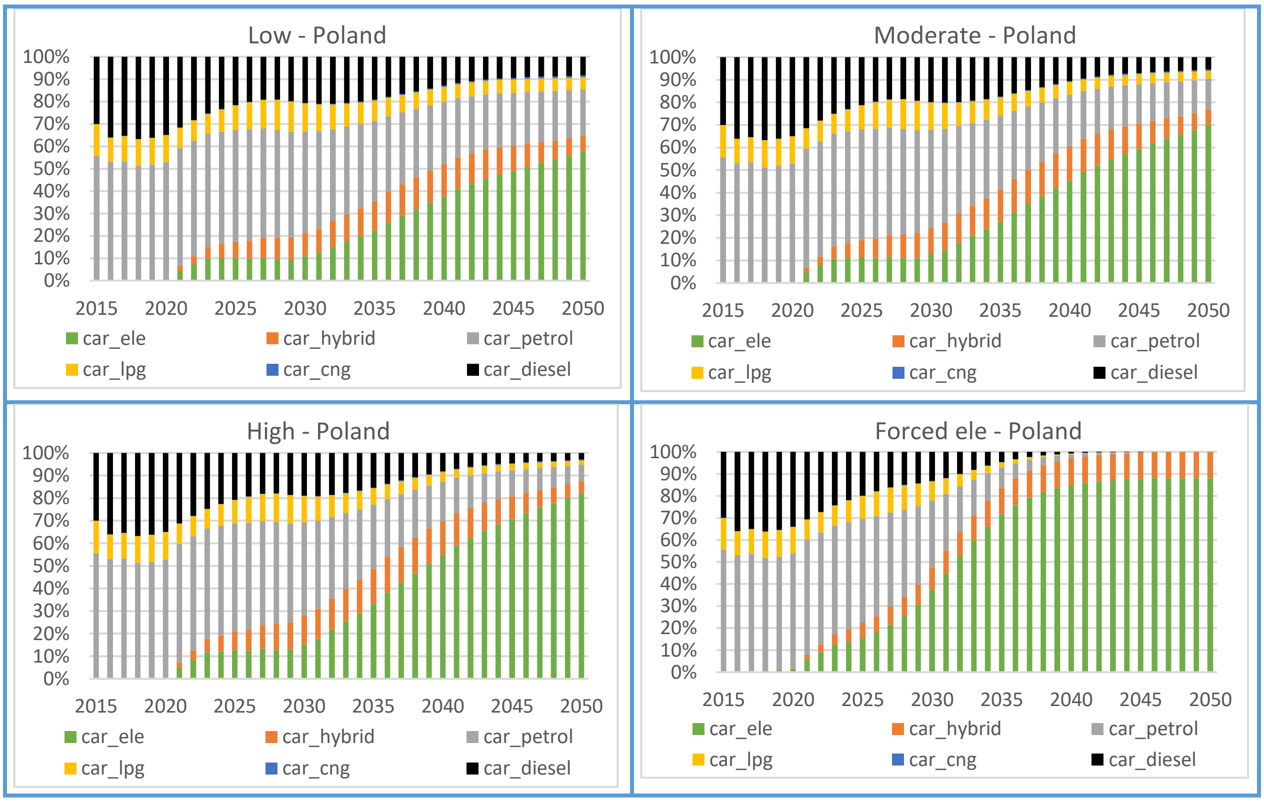





Source: TR³E model

86. The differences in fleets can be seen as well in detailed new cars results in the chart 26. Only in Low, Moderate and High scenarios, ICE vehicles could enter the market up to 2050. In case of Forced electromobility scenario, new ICE vehicles could not be sold after 2040.

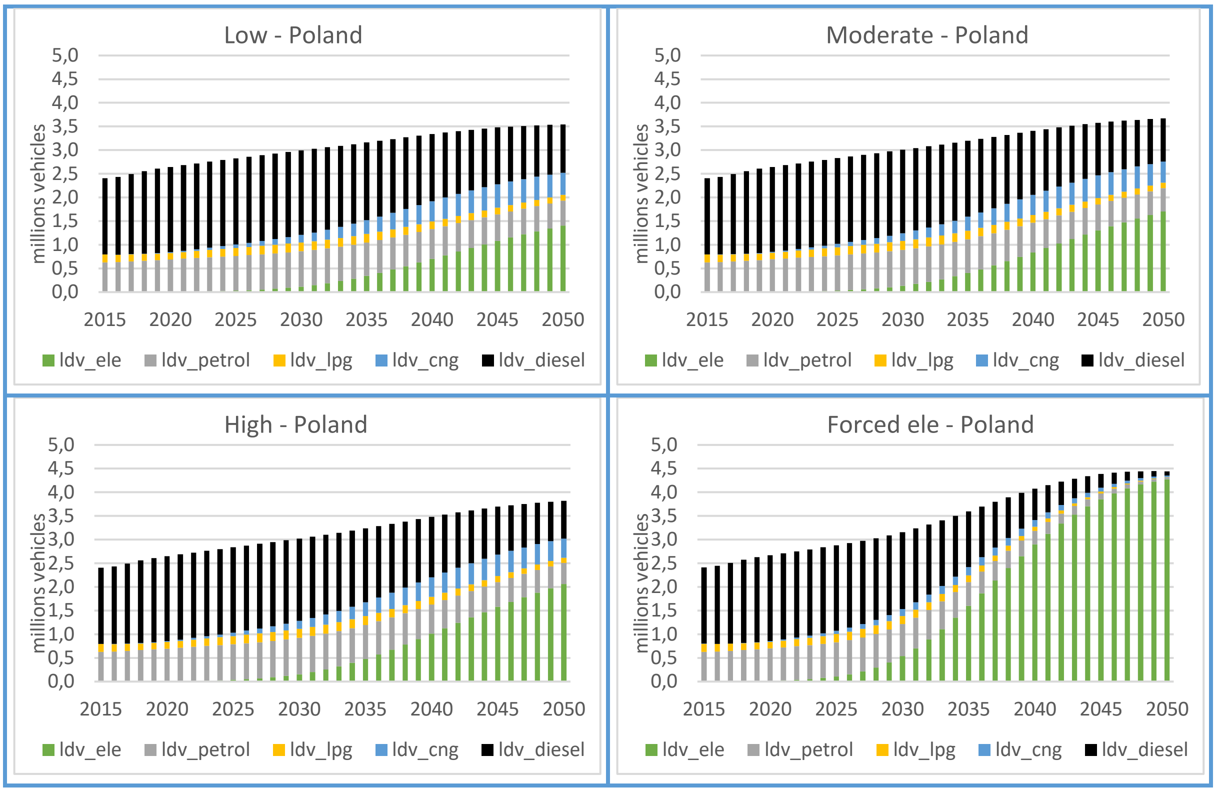
## Figure 26. Structure of new cars fleet in Poland (%)




Source: TR³E model

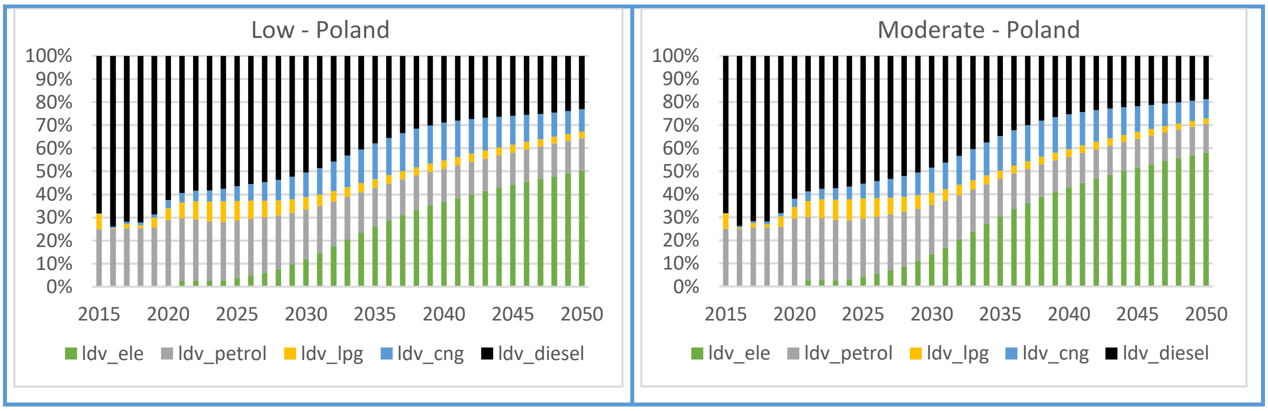
87. In case of LDVs market development in Poland we observe steady growth of total number of vehicles up to 2050 - between 1.4 – 2.0 mln. vehicles in Low – High scenarios. The highest number of LDVs is foreseen in Forced electromobility scenario – over 4 mln. (due to substantial growth in activity and structural changes in fleet – electric LDV's mileage is 2 times lower than diesel ones). What is making the difference is the structure of vehicles types. In Low - High scenarios still ICE vehicles could enter the market up to 2050, what is impossible in Forced electricity scenario (no ICE vehicles after 2040).

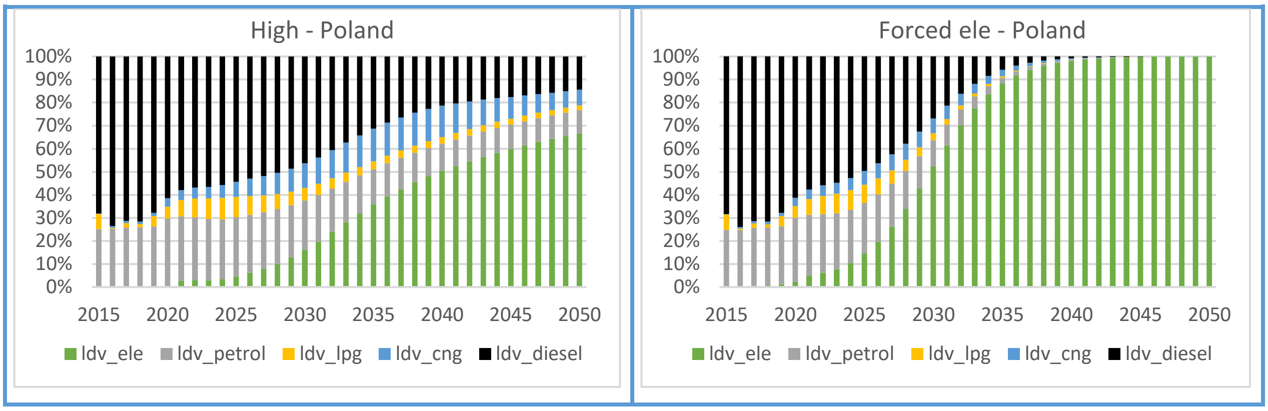
### Figure 27. Structure of LDVs fleet in Poland (millions)




*Source: TR³E model*

### Figure 28. Structure of new LDVs fleet in Poland (%)






*Source: TR³E model*

## 6.4. $CO_2$ emissions

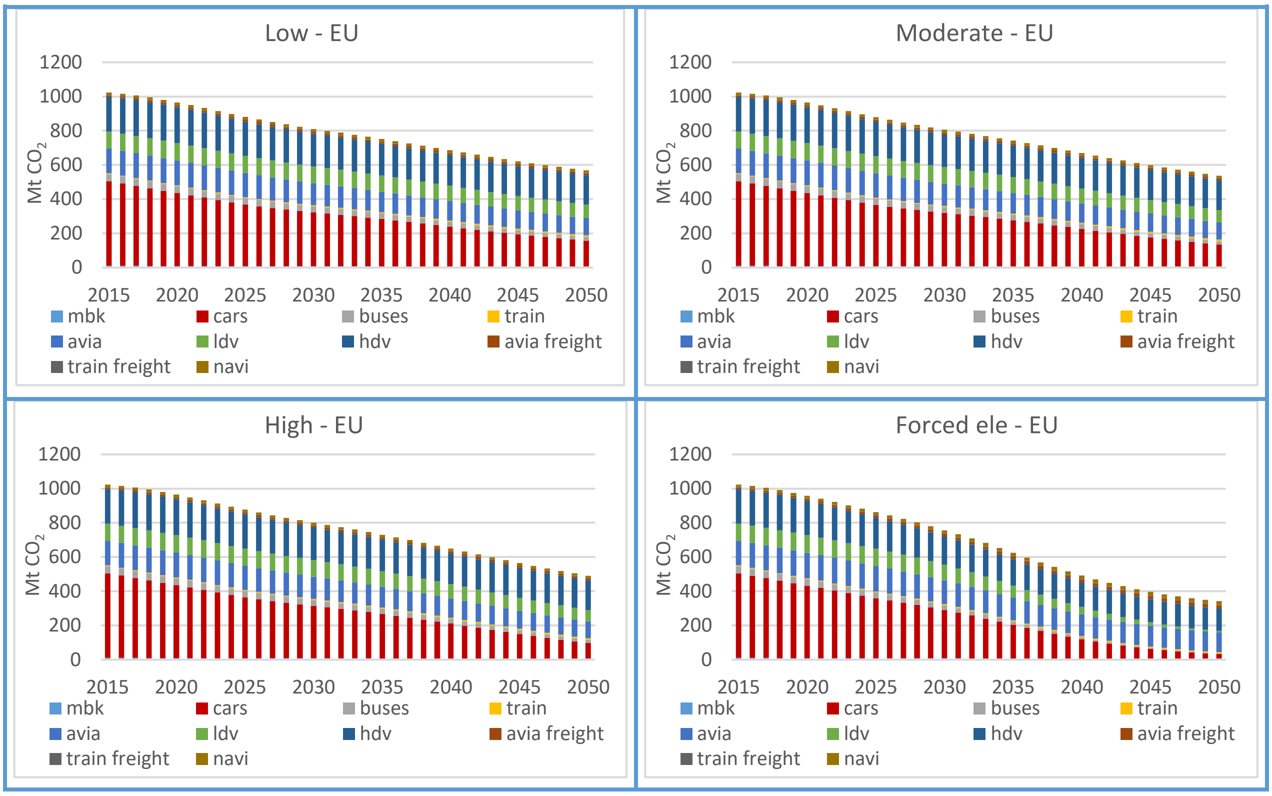
88. There are two main channels of emissions reduction which are visible in the results. The first one is the technology switch within the passenger cars transport and the important growth of low emissions vehicles both in the EU and Poland. Second channel of emissions reduction is linked to the reduced demand for aviation both for passenger and freight transport and linked decrease in activity. In that sub-sector $CO_2$ emissions are more than halved in the analytical scenarios in comparison to the baseline.

89. $CO_2$ emissions in the EU depending on the scenario decline by 45% in 2050 comparing to 2015 in Low scenario and up to 67% in Forced electromobility scenario (47% reduction in Moderate scenario and 52% in High scenario). In Forced electromobility scenario modes of transport the most contributing to these reductions are cars (94% reduction), LDV (94% reduction) and buses (93% reduction). It is important to remind that we do not assume the implementation of ZLEV in the sector of high duty vehicles and no special technologies in aviation sector (apart from efficiency improvement).

90. In case of Poland it is important to notice, that contrary to the EU, $CO_2$ emissions are rising up to 2020 and then they start to decline. This situation is driven by the economic growth of Poland and growing market of new vehicles. If it comes to $CO_2$ emissions reduction there are substantial differences between scenarios. Forced electromobility scenario shows 66% of $CO_2$ emissions reduction potential in 2050 comparing to 2015. In High scenario 45% $CO_2$ emissions reduction is projected, in Moderate scenario - 40%, and in Low scenario 36%.

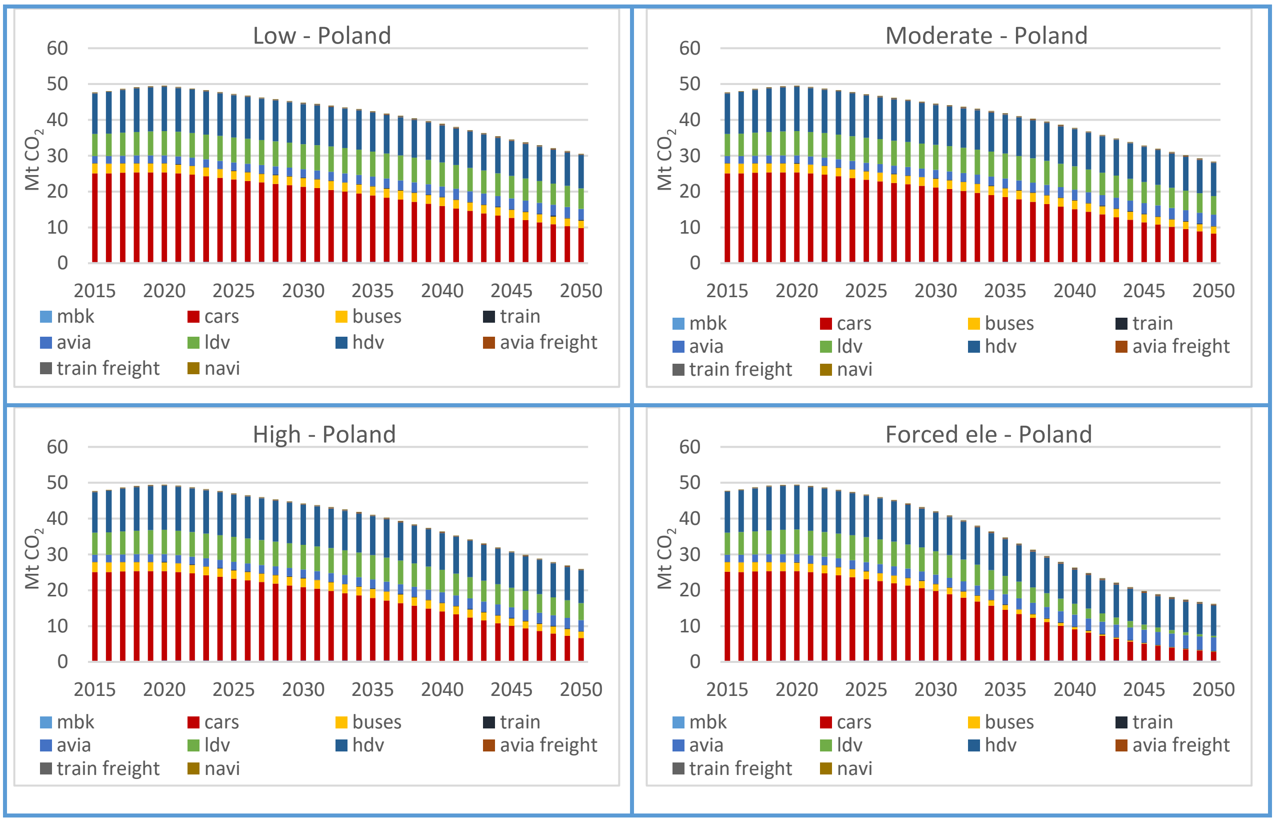
91. If we look at sectoral impacts, it is worth to notice that in Forced electromobility scenario, emissions from cars will drop by 90%, from buses by 98% and from LDVs by 92%. These are the main areas of $CO_2$ emissions reduction in Poland (figure 30).

## Figure 29. $CO_2$ emissions by mean of transport in the EU (Mt $CO_2$)




Source: TR[3]E model

## Figure 30. $CO_2$ emissions by mean of transport in Poland (Mt $CO_2$)




Source: TR[3]E model

## 6.5. Decomposition of $CO_2$ emissions

92. To better understand the drivers of $CO_2$ emissions reduction in transport sector we have proceeded the $CO_2$ emissions decomposition into separate factors. Firstly, we have used Logarithmic Mean Divisia Index (LMDI) method of decomposition because of its easiness to use and to interpret the results (Ang 2004). We have chosen additive decomposition model as its more suitable in the case of quantitative analysis (Ang 2015).

**Figure 31. Decomposition concept**

**LMDI method allows to decompose emissions into following factors:**

$$C = \sum_i C_i = \sum_i ACT \cdot \frac{ACT_i}{ACT} \cdot \frac{C_i}{ACT_i} = \sum_i ACT \cdot sh_i \cdot INT_i$$

**where:**

$C$ – total emissions,

$C_i$ – emissions from mode $i$ (petrol car, diesel car, light duty vehicle, etc.),

$ACT$ - overall activity in transport (passenger and freight),

$ACT_i$ - activity in mode $i$,

$sh_i = \frac{ACT_i}{ACT}$ – share of activity $i$ in total activity,

$INT_i = \frac{C_i}{ACT_i}$ – emissions intensity of activity $i$.

**We can decompose changes in total emissions in two periods 0 and $t$ as:**

$$\begin{aligned}
\Delta C = C^t - C^0 &= \sum_i C_i^t - \sum_i C_i^0 = \sum_i \left( C_i^t - C_i^0 \right) \\
&= \sum_i \frac{C_i^t - C_i^0}{\ln C_i^t - \ln C_i^0} \cdot \ln\left(\frac{C_i^t}{C_i^0}\right) = \sum_i w_i \cdot \ln\left(\frac{C_i^t}{C_i^0}\right) \\
&= \sum_i w_i \cdot \ln\left(\frac{ACT^t \cdot sh_t^i \cdot INT_t^i}{ACT^0 \cdot sh_0^i \cdot INT_0^i}\right) \\
&= \sum_i w_i \cdot \left[\ln\left(\frac{ACT^t}{ACT^0}\right) + \ln\left(\frac{sh_t^i}{sh_0^i}\right) + \ln\left(\frac{INT_t^i}{INT_0^i}\right)\right] \\
&= \sum_i w_i \cdot \ln\left(\frac{ACT^t}{ACT^0}\right) + \sum_i w_i \cdot \ln\left(\frac{sh_t^i}{sh_0^i}\right) + \sum_i w_i \cdot \ln\left(\frac{INT_t^i}{INT_0^i}\right) \\
&= \Delta C_{activity} + \Delta C_{structure} + \Delta C_{intensity}
\end{aligned}$$

Decomposition of $CO_2$ emissions, can provide us with very enriching conclusions. Figure 31. Shows results of decomposition of $CO_2$ emissions into three factors:

- **C_activity** – change of $CO_2$ emissions levels due to growth of transport activity,
- **C_structure** – change of $CO_2$ emissions due to activity shift towards low emissions technologies,
- **C_intensity** – change of $CO_2$ emissions due to improvement of emissions standards, fuel quality ect. (emissions intensity improvement).

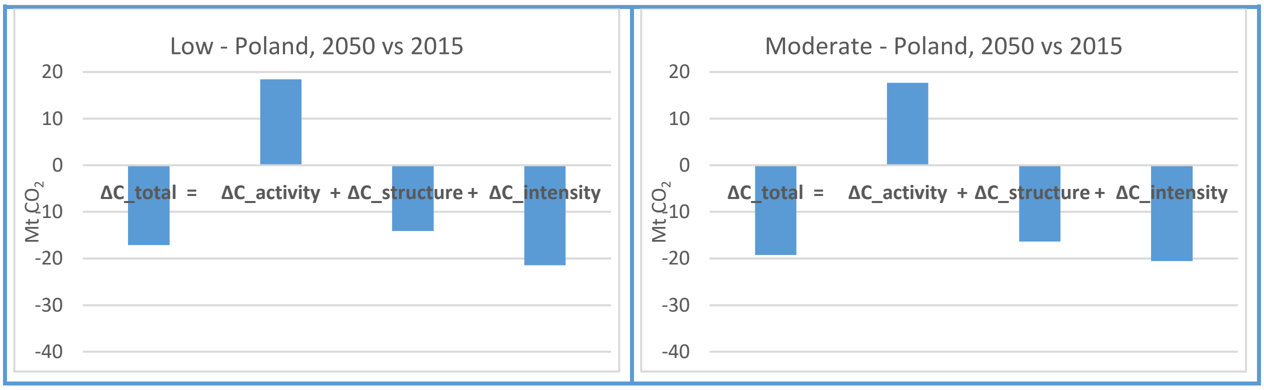
93. Figures 32 and 33 contains the data of total change of $CO_2$ emissions levels (C_total) for Poland and for the EU.

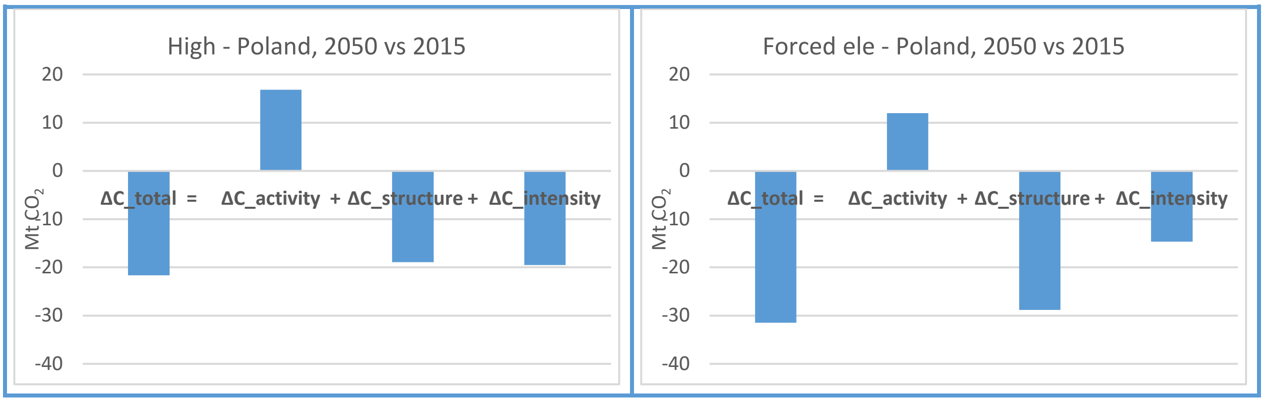
94. Results for Poland for analysed scenarios shows growing importance of change of $CO_2$ emissions due to structural changes in the transport fleet (C_structure is the most important driver of $CO_2$ emissions reductions in the Forced electromobility scenario). Changes (decrease) in carbon intensity of transport activity play important role in $CO_2$ reduction and the level of reduction is higher if the fleet is heavily based on "dirty" technologies (ICE - diesel, petrol).

95. Growth of transport activity as a driver of $CO_2$ emissions levels is the least important in the Forced electromobility scenario (in this scenario there are no incentives to travel in the form of cheaper cars). In Low, Moderate and High scenarios transport activity changes are more less at the same levels.

96. Similar conclusions can be drown in case of emissions intensity. In Low, Moderate and High scenarios this factor plays crucial role in emissions reductions. But in Forced electromobility scenario emissions intensity has lower impact on the $CO_2$ emissions levels comparing to the previous scenarios. This remark is valid both for Poland and for the EU.

**Figure 32. Decomposition of $CO_2$ emissions changes in Poland (2050 vs. 2015)**



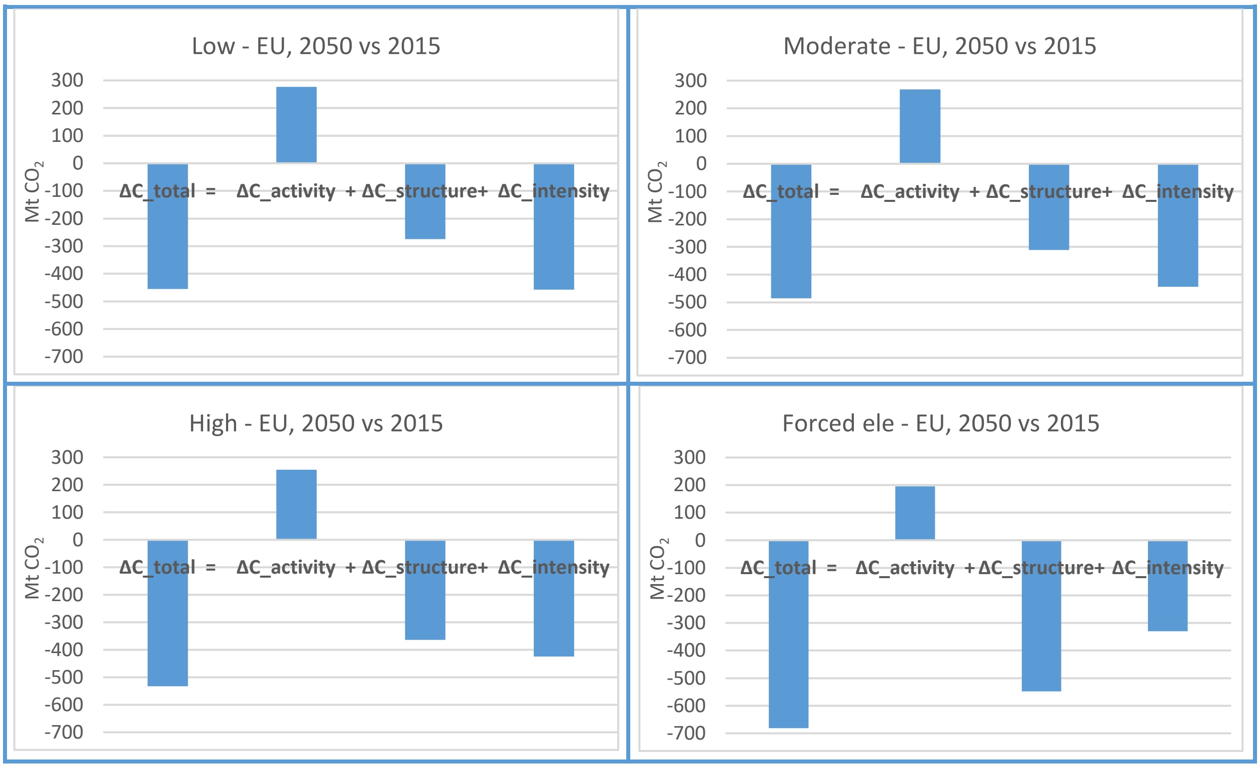



*Source: CAKE/KOBiZE own analysis based onTR³E model results*

97. Results for the EU show declining importance of transport activity for the level of $CO_2$ emissions between the scenarios. In technology progress scenarios (Low – High) changes in emission intensity are the main driver of reduction – over 400 Mt reduction of $CO_2$. Changes in the structure of fleet are responsible for 270 Mt reduction in Low scenario and 360 Mt in High scenario. Growth in transport activity up to 2050 caused growth in emissions less than 200 Mt of $CO_2$ in the Forced electrification scenario and between 250-275 Mt $CO_2$ in technology progress scenarios.

98. In Forced electromobility scenario importance of structural changes has the biggest influence on $CO_2$ reduction – more than 500 Mt meanwhile intensity improvement changes the emissions by about 1/3 of 2015 level.

## Figure 33. Decomposition of $CO_2$ emissions changes in the EU (2050 vs. 2015)



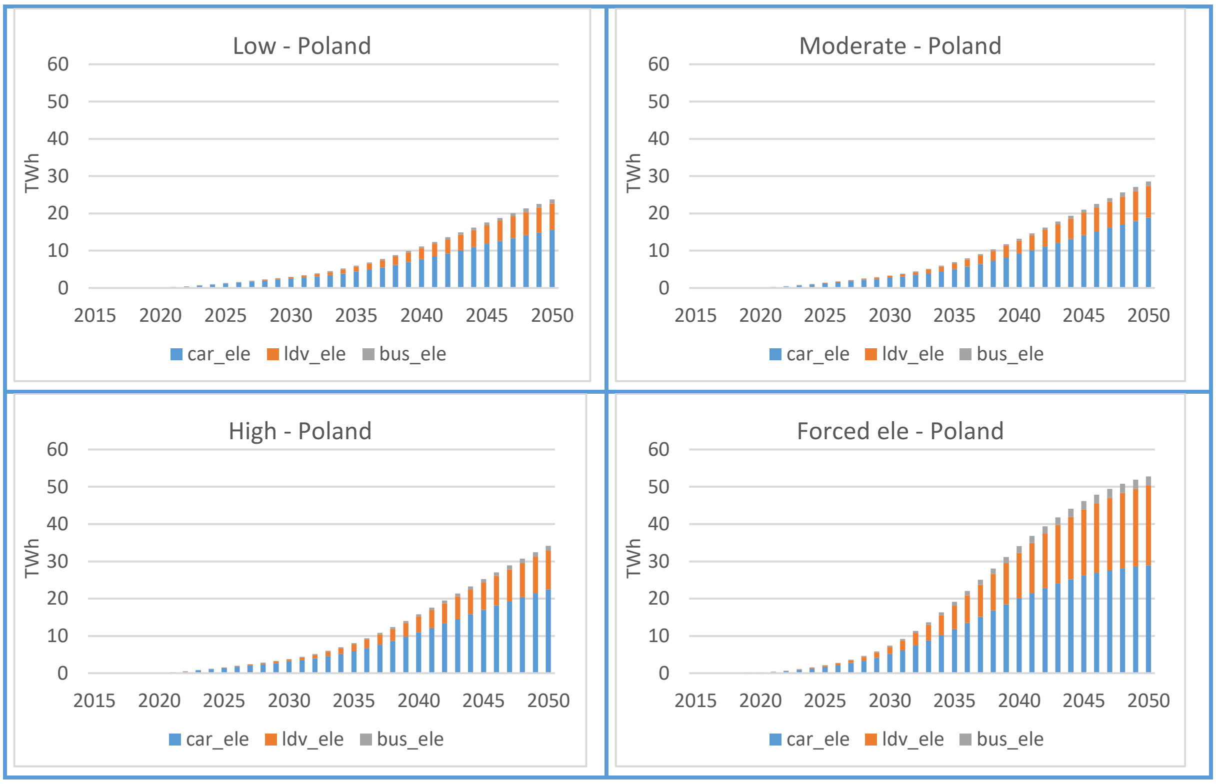

*Source: CAKE/KOBiZE own analysis based onTR³E model results*

99. Comparison of results of this decomposition for Poland and for the EU shows that in Poland impact of changes in transport activity on the $CO_2$ emissions reduction is at the relatively higher level than in the EU due to growth in activity (especially in passenger). General conclusion from this decomposition is that the changes in transport sector structure resulting from new low emission technologies development have the major impact on $CO_2$ emissions reduction as well as changes in carbon intensity of transport activity. This conclusion is founded both for Poland and for the EU.

## 6.6. Electricity consumption – challenges for the energy sector

100. In the technology progress scenarios (Low – High) demand for electricity in Poland is about 30 TWh (in 2050), which is 10-15% of total demand for electricity (assuming that in 2050 the total demand will be on level around 250 TWh). The demand for electricity concerns only new technologies electric cars, electric LDVs and buses, and does not include the electricity to power trains and metro. In Forced electromobility scenario demand for electricity in 2050 will be two times higher than in Low-High scenarios – it is the level 25-30% of total demand for electricity.

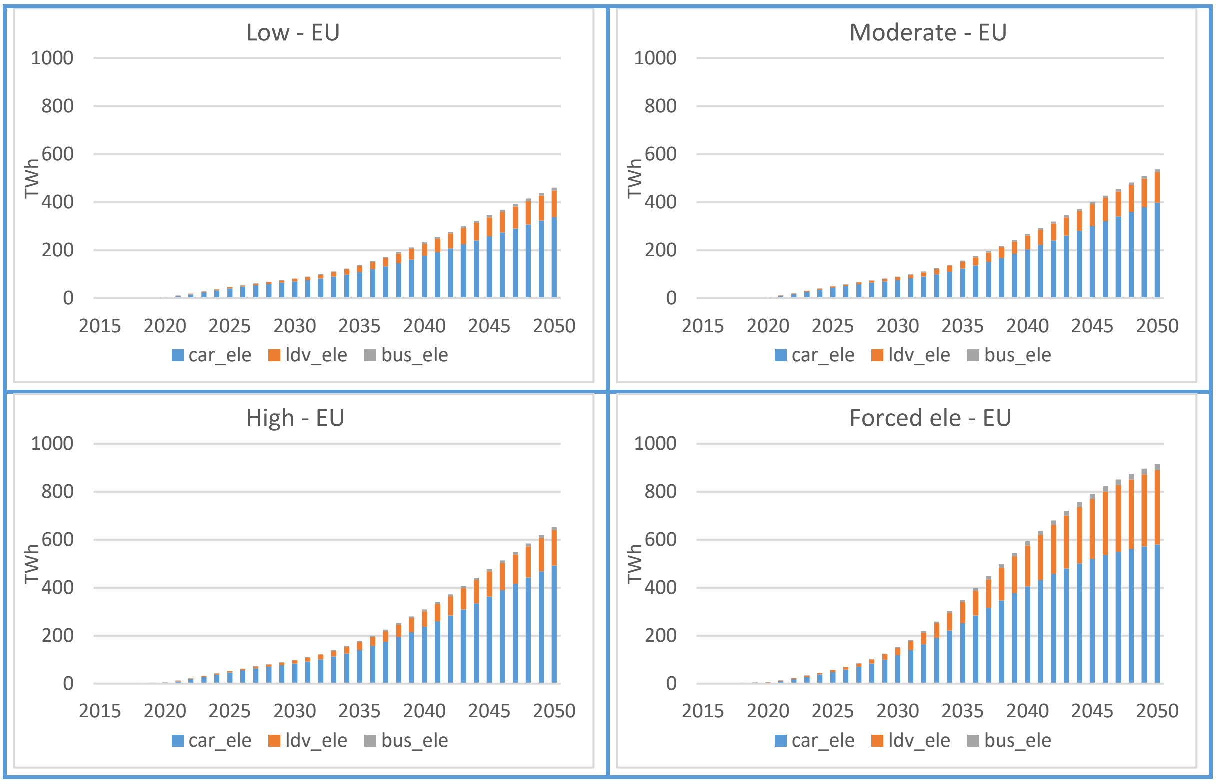
**Figure 34. Demand on electricity by type of vehicles in Poland (TWh)**




*Source: CAKE/KOBiZE own analysis based onTR³E model results*

101. Electricity demand in the EU in 2050 for cars, LDVs and buses is between 460 and 650 TWh in Low – High scenarios, and at level 900 TWh in Forced electromobility scenario. Assuming electricity consumption in 2050 in the EU at level 4000 TWh in Forced scenario demand on additional electricity constitutes about 23% of this amount.

**Figure 35. Demand on electricity by type of vehicles in EU (TWh)**




*Source: CAKE/KOBiZE own analysis based onTR³E model results*

## 6.7. Costs of electromobility in Poland

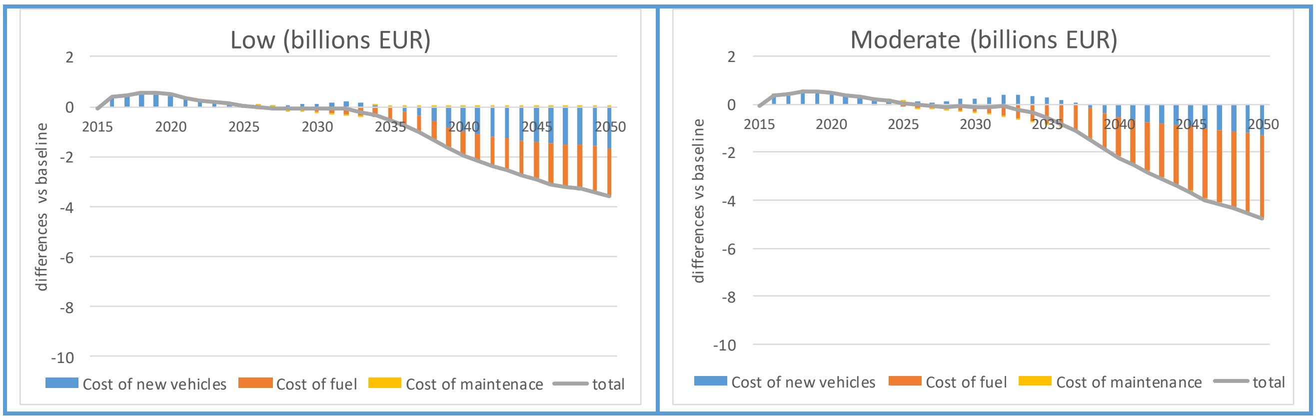
### 6.7.1. User costs of transport

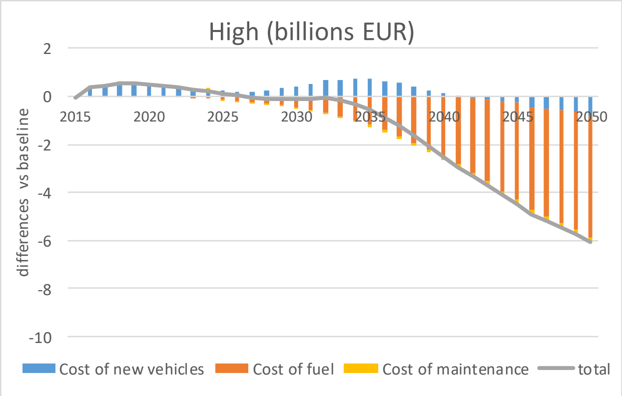
102. User cost of transport are the result of model calculation and depends on the assumptions on the prices of vehicles, prices of maintenance and price of fuels. As fleet information is available only for cars, LDVs, buses and HDVs, these vehicles were taken into account while calculating user costs of mobility. This information were taken from the following sources:

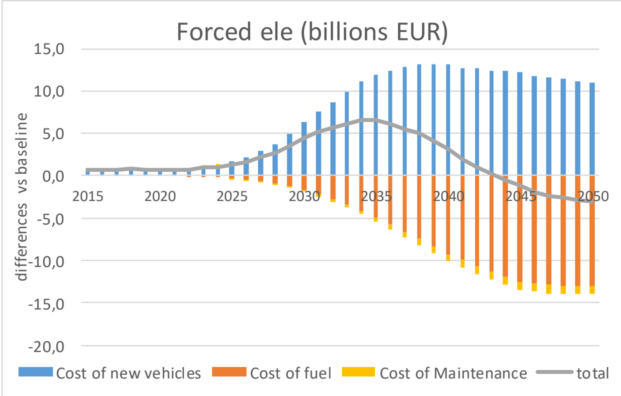
- Basic cost of vehicle is taken from the TRACCS database. We used data for the year 2010 as the most recent one of that dataset.
- Cost of fuels are harmonized with MEESA energy model input. Level of prices of fossil fuel are taken from TRACCS database. Prices dynamics up to 2050 are derived from WEO 2017 current policies scenario, and it is assumed that this prices will rise three times up to 2050. Dynamics for electricity prices are taken from MEESA energy model, and it is assumed two times growth up to 2050.
- Costs of maintenance are taken from TRACCS database and are the same in each scenario (year 2010 data, same as in case of cost of vehicles).

103. The changes to the costs for users are shaped both by the changes in user costs (i.e. modelled shocks to prices of vehicles, fuels and maintenance) as well as by the deviation of baseline use. Therefore, if cheaper means of transport are replaced by more expensive ones, than the cost will increase as a result of changes in transport demand.

**Figure 36. Cost for users (consumers and firms).**






*Source: CAKE/KOBiZE own analysis based onTR³E model results*

104. Lower costs of vehicles as well as changes to prices of electricity and fuel will generate savings in all three technology progress scenarios. The shape of these impact is similar – first, we need to invest some funds (a few hundred millions euro annually), but after 2030 huge savings in costs of fuels will be achieved. This savings will be greater towards the end of the projection period, as the price of fossil fuels will increase and costs of electricity will increase slower due to the deployment of renewable energy sources. In contrary, if costs are held constant than the costs of electromobility are borne by the users. In such case, the savings are smaller and occurs only after 2045, when the costs of more expensive vehicles are balanced by savings on fuels. The total user costs of electromobility in such scenario, cumulated over the period 2020-2050 is equal to almost 71 billion EUR, which is equal to the 2.4 billion EUR annually. This is roughly 0.5% of GDP in Poland in 2018. The highest costs are expected to arise between 2030 and 2035, because the number of electric vehicles will need to increase due to the policies, but the greatest savings from costs of fuels will be visible 10 years later, when almost all vehicles on roads in Poland will be electric.

### 6.7.2. Direct impact on tax revenues

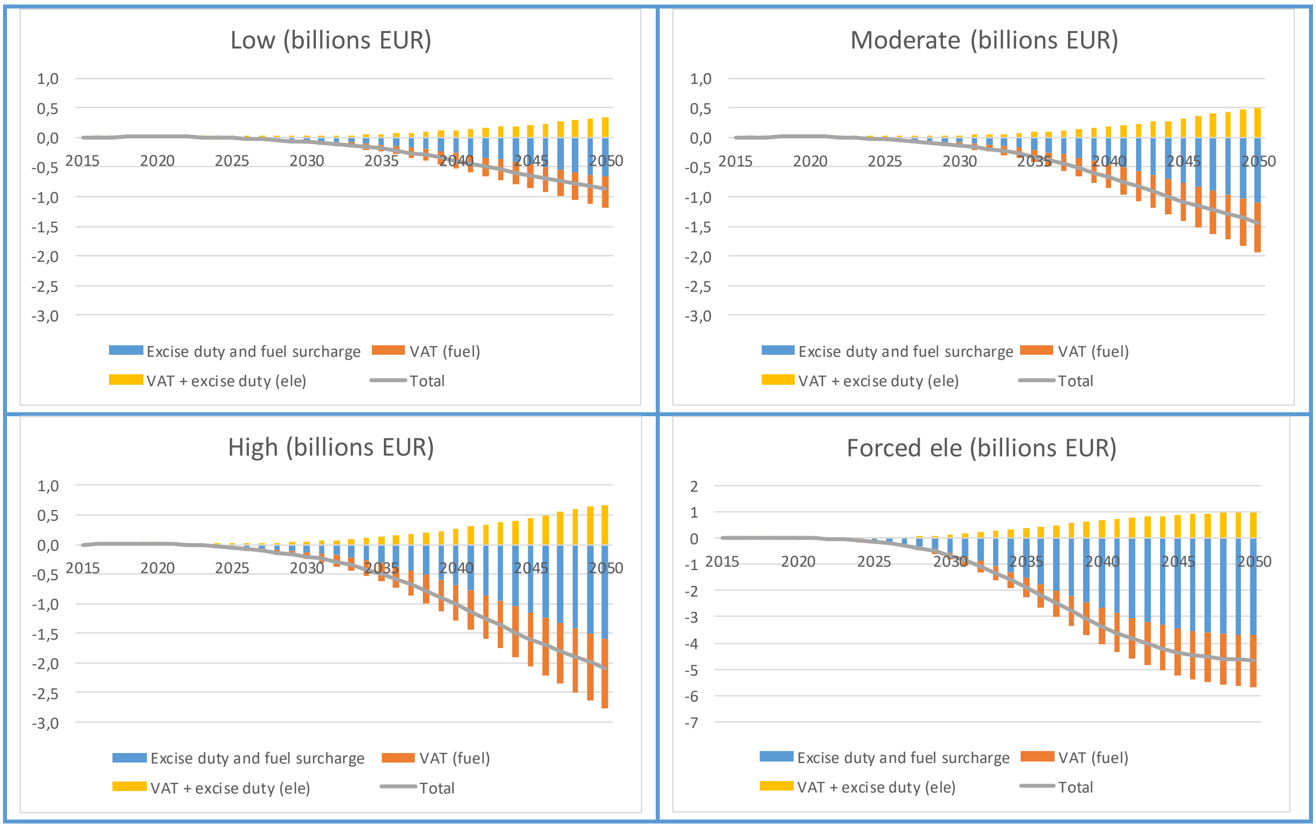
105. The impact of policies on tax revenues is calculated through the multiplication of:

- The use of fuels and electricity as calculated by the model;
- Prices as described in the previous subchapter;
- Excise duty and fuel surcharge is assumed to be held constant in real terms until 2050 and is paid in addition to the net prices of energy (excise duty: 1171 PLN per tonne for oil, 1540 PLN per tonne for petrol, 670 PLN per $m^3$ of gas and 5 PLN per MWh for electricity; fuel surcharge: 297.61 PLN per tonne for oil, 133.21 PLN per tonne for petrol, 164.61 PLN per $m^3$ for gas);

- VAT rates are held constant until 2050 (23% for both electricity and fuels) and are calculated as a percentage of the net price of fuel increased for the excise duty and fuel surcharge.

106. The results of such calculations are presented below. Figure 37 depicts the impact on state revenues, so negative values are losses for state budget.

**Figure 37. Costs - taxes.**




*Source: CAKE/KOBiZE own analysis based onTR³E model results*

107. As expected, the more popular electric cars are, the higher are losses for the state budget. As liquid fuels are much heavier taxed than electricity, the costs for the state budget can be significant and reach 5 billion EUR in 2050 in the most ambitious forced electricity scenario. In case of technical progress these values are smaller - 1-2 billions EUR annually, depending on the assumptions on consumer behavior. However, they reach such values only at the end of projection period – on average, government losses are equal to 0.3-0.8 billions EUR in technology progress scenario and 2.2 billion EUR in the forced electricity scenario.

### 6.7.3. Costs of infrastructure

108. In case of electric vehicles, additional costs of charging infrastructure needs to be covered. In our case, the costs of "slow" (home) chargers and "fast" chargers are calculated separately. Consequently:

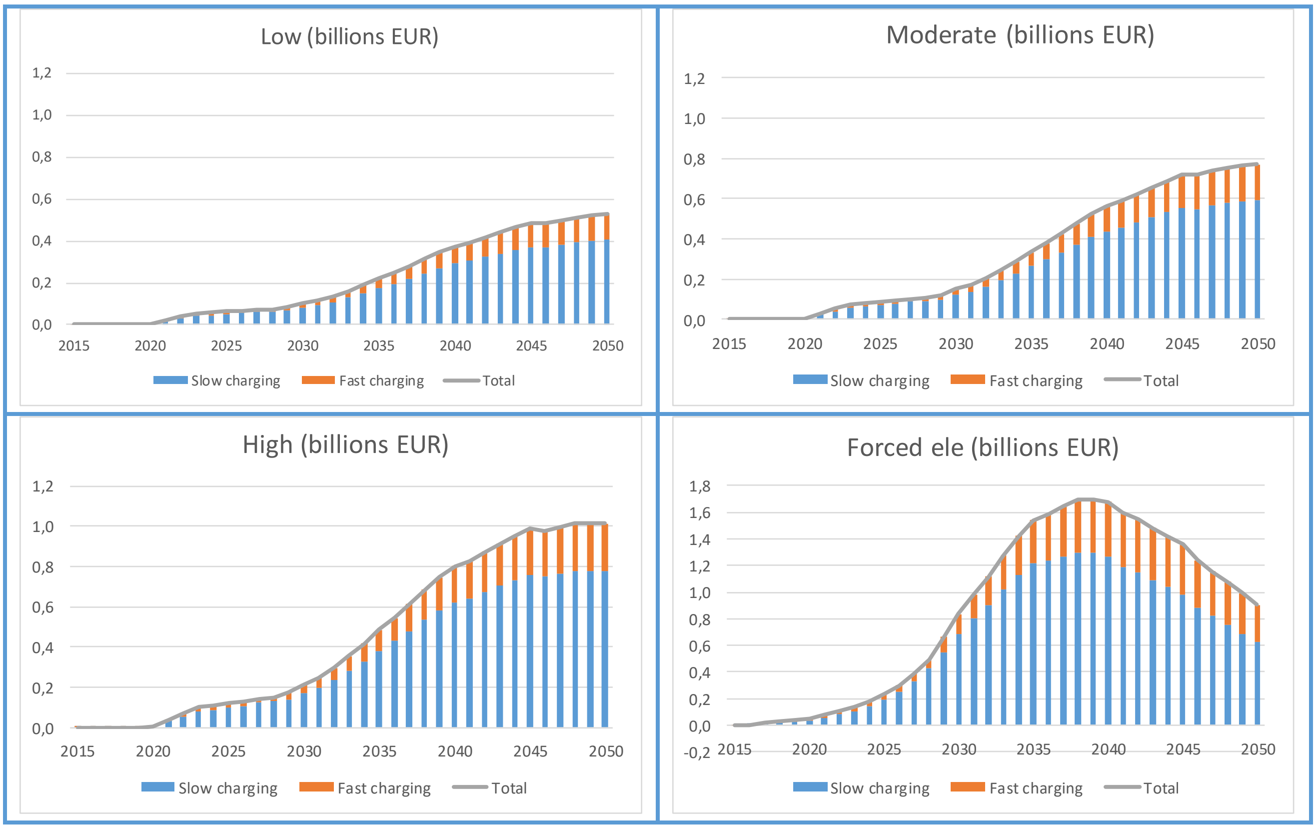
- The number of "slow" (home) chargers depends on the number of electric vehicles. We assume, that the number of owners, who will install slow chargers will decrease in time (in line with increase of commonness of the "fast" chargers). However, at the beginning of the projection there is 0.8 "slow" charger per each car and at the end, this number is equal to 0.5. This assumption can be challenged. In Cambridge Econometric analysis[18] one charger per EV is assumed, in the Eurelectric analysis[19], this number is falling from 93% in 2015 to 15% - 85% in 2050, depending on the scenario.
- The number of fast chargers depends on the percentage of mileage travelled using these chargers (and the following demand for energy), expected use of chargers and expected power. These assumptions also varies across studies. ECF(2018) assumes that 10% of annual demand will be satisfied trough "fast" chargers, in Eurelectric study this is 5% - 50% in 2050, depending on the scenario. Our values are closer to the latter case, in line with assumption on the commonness of "slow" chargers. This value increase from 5% in 2020 to 55% in 2050 for passenger cars, from 5% to 10% for LDVs and is steady at 50% for buses. Motivation for that is that LDVs are used mostly to deliver wares in the cities daily (so they can be charge overnight), while they are rarely used for long-distance transport. In case of buses, this is roughly equal to the division between coaches and urban buses. We assume 50% use of "fast" charger over the course of the day, in line with ECF(2018). Furthermore, the average power of the "fast" charger is assumed to increase from 50 kW in 2020 to almost 100 kW in 2050 in line with the increase in prevalence of fast 150 kW and 350 kW chargers in line with ECF(2018). The depreciation rate is 5% for slow charger (meaning that it needs to be replaced every 20 years) and 15% for fast charger (equivalent to average lifetime of almost 7 years). This numbers are based on expert assessment.
- The average cost of the charger is also very difficult to determine, given the huge range in estimates. ECF (2018) provides cost estimates of 1000-1200 EUR (with installation) for home chargers and ICCT (2019)[20] around 3000 USD. Given low costs of labour in Poland, we decided to adopt 1700 EUR price tag for home charger (with installation). In case of fast chargers, the range is even wider. According to ECF(2018), this number is equal to 25-125 thousands EUR per site, and according to the ICCT(2019), this is

[18] ECF(2018), Low-carbon cars in Europe: A socio-economic assessment, https://www.camecon.com/wp-content/uploads/2018/02/Fuelling-Europes-Future-2018-v1.0.pdf
[19] Eurelectric (2018), "Decarbonisation pathways, EU electrification and decarbonisation scenario modelling", Full study results, Eurelectric, May 2018
[20] ICCT(2019) https://theicct.org/sites/default/files/publications/ICCT_EV_Charging_Cost_20190813.pdf

50-180 thousands of EUR per site. We adopted moderate value of 70 thousand EUR, but this requires further investigation.

109. Based on these assumptions, we reached the following numbers.

### Figure 38. Costs – infrastructure




*Source: CAKE/KOBiZE own analysis based onTR³E model results*

110. In all three technology progress scenarios, the costs increases with time – this is related to the relatively slow deployment of electric vehicles and gradual investment in charging infrastructure. However, if the deployment of electric vehicles is faster (as in case of the forced electromobility scenario), than the investment in infrastructure is required faster and peaks in 2037. After that, most of the infrastructure is already built and used, so the costs are falling.

111. The costs of infrastructure are lower than the losses of the state budget or than the increase in the user cost of mobility. Cumulated costs even in the most ambitious scenario are equal to almost 31 billion of EUR, while in the technology progress scenario, they range between 8 and 16 billion EUR. This translates to annual expenditures of 0.3-0.5 billion EUR in the technology progress scenario and 1 billion EUR in the forced electricity.

### 6.7.4. Costs – summary

112. The range of costs associated with the deployment of electric vehicles is very wide and is subject to large uncertainty. In this subchapter, we aimed at the assessment of three categories of costs that are the most frequently mentioned – the costs for consumer, costs of infrastructure and impact (costs) for the state budget. The total balance crucially depends on the assumption on the prices of electric vehicles.

**Table 6. Costs/profits overview for Poland for the period 2020-2050 (billions EUR)**

| | Cumulated costs/profits (2020-2050) (billions EUR) | | | | Average (yearly) (2020-2050) (billions EUR) | | | |
|---|---|---|---|---|---|---|---|---|
| **Scenario →** | Low | Mod. | High | FE[a)] | Low | Mod. | High | FE[a)] |
| **Consumer Costs(-)/profits (+)** | 34.8 | 43.5 | 52.4 | - 70.8 | 1.2 | 1.4 | 1.7 | -2.4 |
| **Infrastructure Costs** | -7.8 | -11.6 | -16.0 | -30.9 | -0.3 | -0.4 | -0.5 | -1.0 |
| **State budget revenues (+) /loses (-)** | -8.9 | -15.3 | -22.8 | -66.0 | -0.3 | -0.5 | -0.8 | -2.2 |
| **Total** | **18.1** | **16.6** | **13.6** | **-167.6** | **0.6** | **0.6** | **0.5** | **-5.6** |

*Source: CAKE/KOBiZE own presentation*

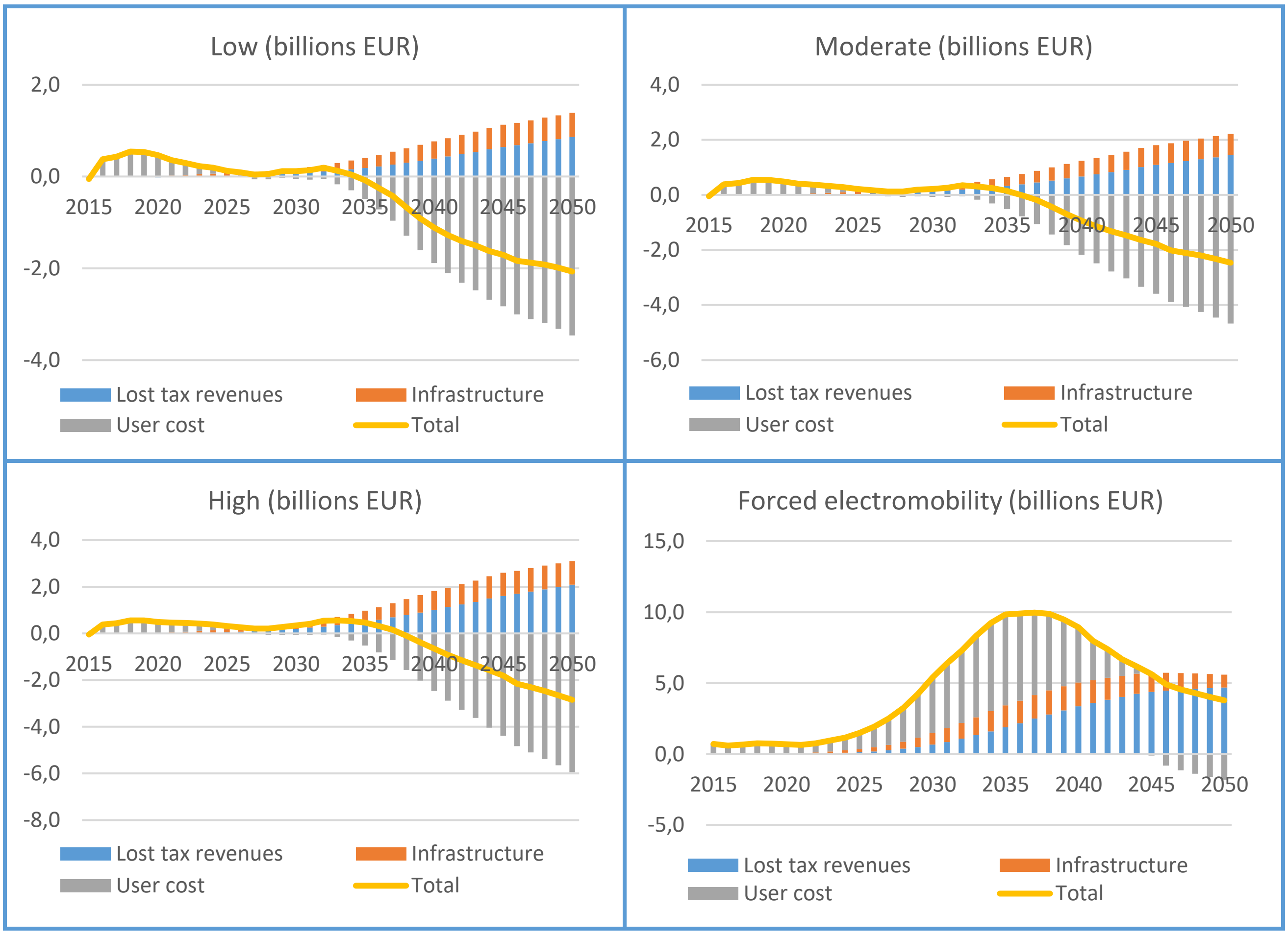
[a)] *FE – Forced electromobility scenario*

113. Change in the user costs of transport is, by and large, the most important position, that affects the total cost and benefits balance of electromobility. In case of technology progress scenarios, where the price of electric vehicles is falling, the user grabs all the benefit (both from lower prices of vehicles and through savings on energy), while in the Forced electromobility scenario, user has to pay most of the bill. The expenditures of state are also substantial, as taxes constitute a huge part of the price of oil and petrol, In all scenarios, the loss of state revenues would be substantial and will increase towards the end of the projection period. Costs of infrastructure are somewhat lower than the remaining positions, but also should not be overlooked in the analysis.

114. In all three scenarios, the costs of infrastructure, vehicles and foregone tax revenues are moderate at the beginning (around 2020) and then increasing over time. On the other side of the equation, we have savings that will be achieved with the lower price of mobility, as travelling 1km with electric vehicle is much cheaper than travelling the same distance with the standard ICE vehicles. These savings occurs, however, much later as infrastructure is already built and fleet is modernized. Therefore, huge initial investments

must be made to achieve savings later. Consequently, to smooth such transition, financial instruments are needed to equalize balance check over time, regardless of the adopted assumptions. This is one of the most important conclusion from the analysis of the costs of electro mobility.

**Figure 39. Total costs**




*Source: CAKE/KOBiZE own analysis based onTR³E model results*

# 8. Conclusions

115. In our analysis, we aimed at presenting different pathways of emission reduction in transport sector in Poland and in the EU. In 2015, transport was responsible for almost a quarter of GHG emission in Poland – therefore emission reduction without touching this sector is virtually impossible. Increase in the popularity of electro mobility as well as reduction of emission in the transport sector is already pursued in different strategic documents and regulation plans.

116. In the analysis, four reduction pathways in transport sector are presented – three, in which the increase in the popularity of electric vehicles is caused by the reduction in price (mainly cost of vehicle) and one in which this is the effect on regulation (we abstract from the feasibility and technical details of such regulation here). All pathways lead to significant reduction of emissions in transport sector – in the EU from 45% to 52% in the scenarios with cost scenarios (technology progress) to 67% in forced electromobility scenario. For Poland, these numbers are 36%-45% and 66% respectively. Consequently, there are possibilities to reduce GHG emissions in transport sector, but this would be quite difficult and can be costly. Moreover, in our simulations, we assume only a small changes in emission intensities for HDVs and air transport – as these means are the main source of emission in 2050, they need to be somehow targeted if net zero emission targets for 2050 are to be completed.

117. Model results are highly sensitive to assumptions on the development of prices of different vehicles. Therefore, the transformation of the transport sector will be shaped by the technical progress and evolution of vehicle prices. Moreover, this assumption shapes also the timing of burden – if costs are falling quickly, then the burden are higher at the beginning of the projection period – if the costs will fall at a slower pace (or not fall at all), the burden will be much higher and the peak will occur later (around 2035).

118. The assumption on the vehicle prices plays crucial role in shaping the user cost of mobility in the future. If this costs will fall 1% annually, than the users will save huge amount of resources (from 35 to 50 billion euro in Poland). This is due mostly to the savings on the costs of fuel – electricity is much cheaper than fossil fuels. In contrary, if electro mobility is to be introduced by the government regulation, user costs will be equal to more than 70 billion euro (2.4 billion annually, on average). Moreover, the cost of infrastructure will add between 0.3 and 1 billion euro annually to the bill and the state budget will need to cover 0.3 to 2.2 billion euro in lost revenue. In general, forced electromobility scenario is the most ambitious one and costs are about twice as high as in “High” scenario, where deployment of electric vehicles is slower. However, also the reduction of $CO_2$ emissions is by 20pp, greater than in any of the “technology progress”

scenarios, where switch to electric vehicles is voluntary and induced by price developments.

119. In real future however, the mix of voluntary and some form of forced transformation will be observed. Development of such scenario is great challenge ahead of researchers and policymakers, but one conclusion is certain – if EU want to achieve zero net emission target in 2050, the transformation of transport sector must accelerate and governments need to act now to achieve substantial emission reductions in transport sector in 2050.

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# Annexes:

## Annex 1: Overview of vehicles categories and vehicle types in TR$^3$E

| Vehicle category | Vehicle types | Details |
|---|---|---|
| **Road transport:** | | |
| • car | 6 vehicle types | petrol, diesel, LPG, gas, hybrid, electric |
| • motorbikes & mopeds | 1 vehicle type | petrol |
| • bus | 5 vehicle type | petrol, diesel, LPG, gas, electric |
| • LDV (freight) | 5 vehicle type | petrol, diesel, LPG, gas, electric |
| • HDV (freight) | 2 vehicle type | domestic, international |
| **Rail transport:** | | |
| • tram/metro | 1 vehicle type | electric |
| • train passenger | 2 vehicle type | diesel, electric |
| • train freight | 2 vehicle type | diesel, electric |
| **Air transport:** | | |
| • plane passenger | 2 vessel types | intra EU, extra EU |
| • plane freight | 2 vessel types | intra EU, extra EU |
| **Water transport:** | | |
| • freight ship | 1 vessel type | inland and coastal |

## Annex 2: $CO_2$ emissions level by mode in Poland (analytical scenarios)

| Scenario | $CO_2$ emissions (Mt) | | | |
|---|---|---|---|---|
| **Low** | **2015** | **2030** | **2040** | **2050** |
| Mbk | 0.3 | 0.4 | 0.4 | 0.3 |
| Cars | 24.8 | 21.0 | 15.6 | 9.5 |
| Buses | 2.7 | 2.4 | 2.5 | 2.1 |
| Train | 0.1 | 0.2 | 0.2 | 0.2 |
| Avia | 2.0 | 2.3 | 2.9 | 3.1 |
| Ldv | 6.1 | 7.0 | 6.7 | 5.7 |
| Hdv | 11.3 | 11.1 | 10.3 | 9.3 |
| avia freight | 0.0 | 0.1 | 0.1 | 0.1 |
| train freight | 0.2 | 0.2 | 0.2 | 0.2 |
| Navi | 0.0 | 0.0 | 0.0 | 0.0 |
| **Total** | **47.5** | **44.7** | **38.9** | **30.5** |

| Scenario | $CO_2$ emissions (Mt) | | | |
|---|---|---|---|---|
| **Moderate** | **2015** | **2030** | **2040** | **2050** |
| Mbk | 0.3 | 0.4 | 0.4 | 0.3 |
| Cars | 24.8 | 20.7 | 14.8 | 8.0 |
| buses | 2.7 | 2.4 | 2.4 | 2.0 |
| train | 0.1 | 0.2 | 0.2 | 0.2 |
| avia | 2.0 | 2.3 | 2.9 | 3.1 |
| ldv | 6.1 | 7.0 | 6.5 | 5.3 |
| hdv | 11.3 | 11.1 | 10.3 | 9.3 |
| avia freight | 0.0 | 0.1 | 0.1 | 0.1 |
| train freight | 0.2 | 0.2 | 0.2 | 0.2 |
| navi | 0.0 | 0.0 | 0.0 | 0.0 |
| **Total** | **47.5** | **44.4** | **37.8** | **28.5** |

| Scenario | $CO_2$ emissions (Mt) | | | |
|---|---|---|---|---|
| **High** | **2015** | **2030** | **2040** | **2050** |
| mbk | 0.3 | 0.4 | 0.3 | 0.3 |
| cars | 24.8 | 20.5 | 13.8 | 6.4 |
| buses | 2.7 | 2.4 | 2.3 | 1.8 |
| train | 0.1 | 0.2 | 0.2 | 0.2 |
| avia | 2.0 | 2.3 | 2.8 | 3.0 |
| ldv | 6.1 | 6.9 | 6.2 | 4.7 |
| hdv | 11.3 | 11.1 | 10.3 | 9.3 |
| avia freight | 0.0 | 0.1 | 0.1 | 0.1 |
| train freight | 0.2 | 0.2 | 0.2 | 0.2 |
| navi | 0.0 | 0.0 | 0.0 | 0.0 |
| **Total** | **47.5** | **44.1** | **36.2** | **26.0** |

| Scenario | $CO_2$ emissions (Mt) | | | |
|---|---|---|---|---|
| **Forced ele.** | **2015** | **2030** | **2040** | **2050** |
| mbk | 0.3 | 0.4 | 0.4 | 0.4 |
| cars | 24.8 | 19.3 | 8.7 | 2.5 |
| buses | 2.7 | 1.9 | 0.6 | 0.1 |
| train | 0.1 | 0.1 | 0.2 | 0.2 |
| avia | 2.0 | 2.6 | 3.3 | 3.7 |
| ldv | 6.1 | 6.5 | 3.1 | 0.5 |
| hdv | 11.3 | 10.7 | 9.6 | 8.4 |
| avia freight | 0.0 | 0.1 | 0.2 | 0.2 |
| train freight | 0.2 | 0.2 | 0.2 | 0.2 |
| navi | 0.0 | 0.0 | 0.0 | 0.0 |
| **Total** | **47.5** | **41.8** | **26.3** | **16.2** |