STUDY ON THE TRANSPORT SECTOR
ANALYSIS OF POLICIES AND MEASURES
STUTRA

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	Macedonian	English
BEV	Електрични возила со батерија	Battery Electric Vehicle
FCEV	Електрични возила со горивни ќелии	Fuel Cell Electric Vehicle
IEA	Меѓународна агенција за енергетика	International Energy Agency
PHEV	„Plug-in“ хибридни електрични возила	Plug-in Hybrid Electric Vehicle
SBUR	Втор двогодишен извештај за климатски промени	Second Biennial Update Report
WAM	(Сценарио) со дополнителни мерки	With Additional Measures
WEM	(Сценарио) со постојни мерки	With Existing Measures
WOM	(Сценарио) без мерки	WithOut measures

Introduction

The transition from a society where fossil fuels are the main energy source to a low-carbon society where more efficient technologies are predominantly used, but also renewable energy sources, requires engagement of all stakeholders, of politicians but also of regular citizens. When we talk about decarbonization of the society we generally refer to the decarbonization of the Energy Sector which mostly contributes to the increasing GHG emissions. One category from this sector which has the highest share of GHG emissions is the category of Energy Industry, which means electricity production. This system by itself is quite complex, but without doubt it has high decarbonization potential, above all by introduction of renewable energy sources, which on the other hand introduce a lot of insecurity in the system, especially wind and solar power plants.

The fastest growing category in the energy sector is the category of transport which is also quite complex and has limited potential for GHG emissions reductions. By increasing the efficiency of conventional vehicles, one can contribute to reducing GHG emissions, but only to a certain extent because efficiency is finite. Electric vehicles can contribute to reducing the GHG emissions but they are still controversial/disputable in countries where coal is mostly used for energy production.

Unification of the transport and the energy industries categories is seen specifically through the prism of electric vehicles. They can be seen as one of the best options which can help for decarbonization of transport, and on the other hand it can contribute for greater integration of renewable energy sources. Additional benefits from the introduction of hybrid and electric vehicles are the radical reduction of local pollution and traffic safety, thus improving the life of people.

In the last years there is a growing trend of energy consumption in the transport category. Namely, in Macedonia the contribution of transport in final consumption has increased from 24% in 2012 to 32.5% in 2015. Out of the three subcategories (road, railway and air transport), the most dominant is the road transport, contributing with 97% in the final energy consumption. The biggest element in the section of passenger motor vehicles are the passenger cars - 87%. This is one of the reasons why this subcategory will be the subject of analysis in this Study.

From GHG emissions perspective, in 2014 the transport sector contributed with 13% in the total national GHG emissions, and with 20.5% in the total emissions in the Energy Sector. In the most recent years we can see a growing trend in the emissions from this category, so in 2014 emissions are for 3.6% higher than in 2013 and for 16.4% higher in comparison to 2012. Taking into consideration that road transport is the biggest source of GHG emissions (almost 99%) in the transport sector, the measures and policies for emission reduction should be mostly focused on this type of transport. These policies and measures should be mostly focused on increasing the efficiency of vehicles and electrification of transport.

When analyzing the electrification of the transport, we have to take into consideration the rapidly growing number of electrical vehicles on global level. The leading countries in the world in the number of electric vehicles are China, USA and Japan and the electric vehicles in these countries make 2/3 of the total number of electric vehicles on global level. Having in mind the development of the markets for electric vehicles in the leading countries in the world and knowing that Macedonia does not have its own vehicle production industry, it seems inevitable that

Macedonia as a country will have to follow these trends, which contributes to decarbonization of the transport sector.

Still, at this stage of market distribution of electric vehicles, support policies are needed in order to reduce the barriers for adoption of technology. Such environment with supporting policies will enable market growth by making the vehicles attractive for the consumers, it will reduce risks for investors and encourage manufacturers prepared to develop large scale production capacities for electric vehicles in large scale to start and implement their plans. Due to this, based on the analyses made about the conditions in the transport sector in Macedonia, as well as having in mind the situation on the market of electric vehicles in Europe and in the world, it is necessary to determine policies and measures which would define the direction for development of the transport sector in Macedonia.

Objective of the STUTRA Study

This study proposes measures and policies which would enable increasing the efficiency and electrification of passenger cars in Macedonia.

Also, an analytical modelling was made in order to determine the effect of the proposed measures and policies, by quantifying the mitigation potential and the potential for the following:

a. increasing the share of low-carbon cars being part of the mix,
b. enhancing the phasing out high-carbon cars from the traffic,
c. increasing the share of hybrid and electric cars.

Additionally, the Study assesses the contribution of transport electrification to increasing the share of renewable energy sources, by analyzing the electric cars and their impact on consumption.

The electric cars market in the world and in Europe

The electric cars[1] today make 0.2% of the of the total number of passenger cars in circulation. According to the publication "Global Electric Vehicle Outlook, 2017" of the International Energy Agency (IEA)[2], since 2010 onward, the number of electric cars on global level is rapidly increasing, so of about 2000 vehicles in 2005, in 2016 there are more than 2 million vehicles, after in 2015 it passed 1 million (Figure 1).

This shift in the electric cars industry is attributed to three factors:

- The increased global cost for renewing the fossil fuels used in conventional cars;
- The environmental potential of electric cars, which generate less CO_2 emissions, compared to cars using engine petrol, thus assisting the reduction of GHG emissions which contribute to climate change;
- Lower fuel cost for electric cars on some markets, especially in the US.

Regulatory incentives, the infrastructure for supporting electric cars, the size of the market and other factors contribute to various level of penetration of this cars in the world. So, on the global market for electric cars, the US, China and Japan are leading countries in the number of electric cars, and they cover more than 2/3 of the total number of electric cars on global level (see Figure 1), and the EU member countries comprise only 28%. Battery electric vehicles (BEVs) still are the most numerous, they comprise 60% of the total number of electric cars. Their share has not changes significantly since 2012 and varies around this value.

Until 2015, the USA had the highest share in the total number of electric cars on global level. In 2016, China took the top position, with almost 1/3 of the total number of electric cars in the world. With more than 200 million "two-wheelers" motorcycles[3], 3 to 4 million low-speed electric vehicles - LSEVs and more than 300.000 electric buses, China is also a global leader in the electrification of other modes of transport (types of vehicles). As the number of electric cars is increasing on the roads, so is the private and the publicly available infrastructure for charging the vehicles. In 2016, the annual growth rate for publicly available chargers (72%) was higher, but similar was the growth rate of the number of electric cars in the same year (60%).

Sources: IEA analysis based on submissions from the countries members of Electric Vehicle Initiative, amended with data from EAFO (2017a), IHS Polk (2016), MarkLines (2017), ACEA (2017a, 2017b) and EEA (2017).

[1] electric cars include: battery electric vehicles (BEVs), „plug-in" hybrid electric vehicles (PHEVs) and fuel cell electric vehicles (FCEVs) in the section passenger light-duty vehicles - PLDVs), but in this Study, due to their greater expansion, we have taken into consideration only BEVs and PHEVs

[2] https://www.iea.org/publications/freepublications/publication/GlobalEVOutlook2017.pdf

[3] The terms "two-wheelers" relates to motocycles and does not inlcude

Remarks: The number of electric cars presented in the Figure mainly is assessed based on the cumulative value of the sales from 2005. Depending on the availability, we have used the number of cars from the official national statistics, which enabled us to have good consistency in the development of the sales.

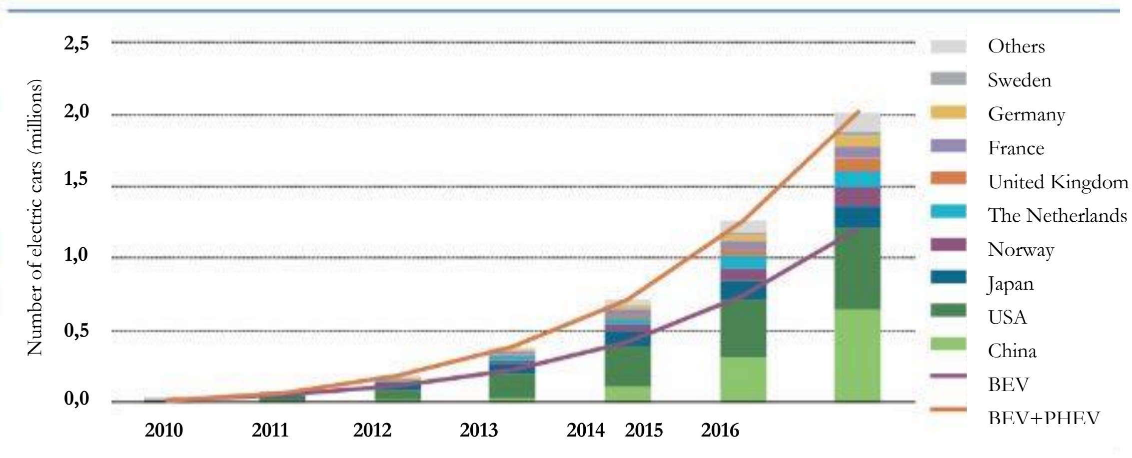
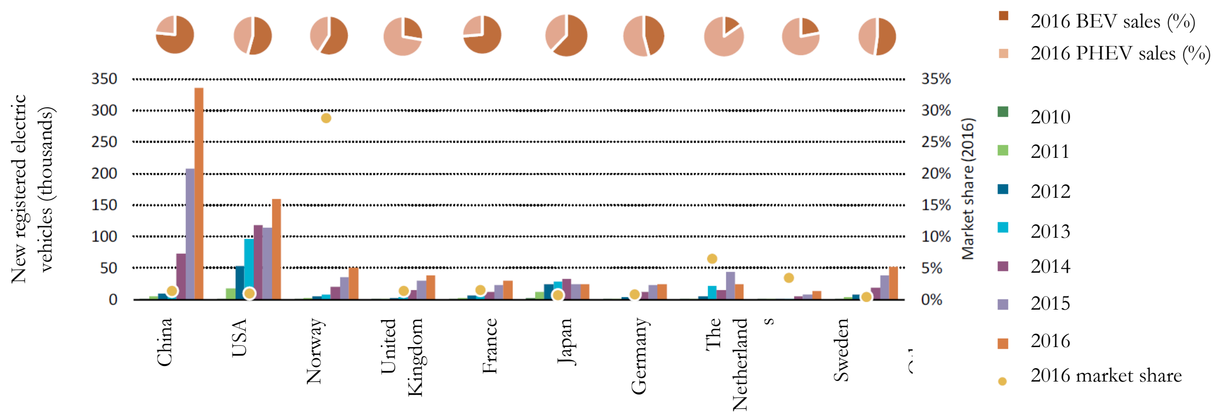


Figure 1. Developments in the number of electric vehicles on global level, for the period 2010 – 2016

The registration of new electric cars reached a new record in 2016, with more than 750,000 cars sold around the world (1% from the market). With a market share of 29%[4], there is no doubt that on global level, Norway has achieved most successfull distribution of electric cars from the point of view of the market share. Then we have the Netherlands with a share of 6.4% of electric cars and Sweden with 3.4%. In China, France and Great Britain the market share of electric cars is close to 1.5%. In 2016, the biggest market for electric cars was in China, where more than 40% of all electric cars in the world are sold (336,000 newly registered vehicles) and this number is more than double of the electric cars sold in the US (160,000 newly regisered cars) (Figure 2). 215,000 electric cars are sold in the European countries[5]. Taking all this in consideration, and the situation on global and on EU level, the market of electric cars is still mainly focused on several countries. In Europe, most of the electric cars in 2016 are registered only in 6 countries: Norway, Great Britain, France, Germany, the Netherlands and Sweden.

[4] The market share is defined as a percent of new registered electric cars from the total number of all PLDVs.
[5] In this case, the European countries include all countries geografically located in Europe which submit data to the Electric Vehicle Initiative and European Alternative Fuels Observatory.



Sources: IEA analysis based on submissions from the countries members of Electric Vehicle Initiative, amended with data from EAFO (2017a), IHS Polk (2016), MarkLines (2017), ACEA (2017a, 2017b) and EEA (2017).

Figure 2. Sales of electric vehicles, market share and share of BEV and PHEV sold in the analyzed countries, for the period 2010 – 2016

The high share of electric cars on the Norwegian market is a result of the favorable political environment in the recent years, which entails a lot of incentives, such as tax reductions and tax exemptions but also not paying tolls and ferry tickets.

As in the case with sales, different countries have different features. Electric cars in China, France and Norway primarily consist of battery electric vehicles (BEVs). The Netherlands clearly is a country with the highest share of "plug-in" hybrid vehicles (PHEVs) which present 88% of the total number of electric vehicles. The third group of countries, including Canada and the US, have pretty balanced distribution of PHEV and BEV in the total number of electric cars.

Significant changes were noticed on the market for electric vehicles in 2016, compared to 2015. Table 1 presents an overview of these high-level changes, connecting quality indicators for the transformation of mechanisms for financial support for buying electric cars between 2015 and 2016 and the annual changes in the registration of BEV and PHEV.

Table 1. Development of incentives in several selected countries in 2016 [6]

Country	Development of policies in 2016 compared to 2015		Increased sales in 2016 in comparison to 2015		Sales in 2016	
	BEV	PHEV	BEV	PHEV	BEV	PHEV
China	~		75%	30%	257,000	79,000
USA	~		22%	70%	86,731	72,885
Norway	~	↗	6%	164%	29,520	20,660
Great Britain	~		4%	42%	10,509	27,403
France	~		26%	36%	21,758	7,749
Japan	~		48%	-34%	15,461	9,390
Germany	~		-6%	20%	11,322	13,290
The Netherlands	~	↘	47%	-50%	3,737	20,740
Sweden	~	↘	0%	86%	2,951	10,464
Canada	~		19%	147%	5,220	6,360
Denmark	↘		-71%	-49%	1,218	182

[6] https://www.iea.org/publications/freepublications/publication/GlobalEVOutlook2017.pdf

Korea	~	75%	-40%	5,099	164

Remarks: The symbol ~ shows that there are no greater changes in the incentives for supporting the sales of electric cars between 2015 and 2016; upward arrow shows that the incentives were increased; and downward arrow shows that the incentives for supporting the sales of electric cars were reduced.
The green and the red color show that there is probable relation between the development of the support measures for electric cars and the sales of BEV and PHEV in 2016 compared to the previous year.
The sales of PHEV in Denmark and Korea were taken from primary sources of data in relation to hybrid and electric vehicles (HEVs). Consequently, the sales of PHEV presented in this table for Denmark and Korea rely primarily on assessments based on the sources listed bellow and might be underestimated.
Sources: IEA analysis based on submissions from the countries members of Electric Vehicle Initiative, amended with data from EAFO (2017a), IHS Polk (2016), MarkLines (2017), ACEA (2017a, 2017b) and EEA (2017).

Policies and measures applied in the countries listed in Table 1, in order to achieve the presented changes are explained in continuation.

- Policies in China in 2016 continued to provide strong financial and non-financial incentives for the penetration of electric vehicles. Tax and excise duty exemptions range from 35,000 and 60,000 CNY (5,000 – 8,500 USD). Local and regional governments can additionally incentivize within the limit of 50% of the amount of the central subsidies. Big Chinese cities, also permit complete or partial exemptions from the limitations in regard to availability of registration plates for cars. The combination of imposing limitations on registration plates, encouragement of consumers to buy electric cars and the offering of financial incentives - making the electric cars more financially affordable - explains the high sales (336,000 cars) and the growth rate (40%) in 2016 compared to 2015 (Table 1). In their plan for the period 2016-2020 titled "Schemes for Subsidizing and Technical Requirements of Products for the Objective of Promoting New Energy Vehicles", the Chinese Government announced that the subsidies for electric vehicles will be reduced for 20% in 2017 and further on, admitting its intention continuously to adjust and improve its policies in order to contribute for optimized market response. Even with these changes, at the beginning of 2017 the market for electric cars in China continued to grow.
- In Norway, the electric cars are exempted from paying taxes, which actually presents a subsidy of about 100,000 NOK (11,600 USD). BEV are exempted from VAT, which is 25% for buying cars. Such actions, together with the high number of exemptions, such as not paying tolls and ferry tickets, continue to ensure very favorable environment for the penetration of electric cars, especially for BEV. Taxation of BEV is expected to remain unchanged until 2020, while in 2016 higher discounts for buying PHEV and tax exemptions were introduced compared to 2015. Since 2016 free parking for electric cars is no longer applicable throughout the country. The sales of BEV reached the record level in 2016, but it did not grow considerably in relation to 2015. On the other hand, the sales of PHEV significantly grew, doubling the numbers in just one year. This was in line with the changes in the policy support. Other factors which could have significant impact on the sales are changes in the availability of BEV and PHEV models and the increased interest in electric cars from clients who often travel long distances (these clients potentially favor the sales of PHEV).
- In Japan, a new subsidy scheme was introduced in 2016, which progressively increased the subsidies for high range electric vehicles (more kilometers with one charging), with maximum subsidy of 850,000 JPY (7, 700 USD). For Nissan Leaf with battery of 30 kWh, the incentive is 330,000 JPY (3,000 USD). The sales of BEV (usually with bigger batteries and greater electric range from PHEV) are increased for almost 50% in 2016, while the sales of PHEV fell for 34%. Other factors which explain this evolution on the market includes the introduction of the new Nissan Leaf in 2016, as well as the negative impact of the alleged forgery of the fuel economy standards in the Mitsubishi models.
- The Netherlands has differentiated taxation scheme based on CO_2 emissions, for which tax rates will gradually change until 2020 (the rates for every year until 2020 are already published). The changes primarily influence PHEV, for which the tax rates will continue

to increase compared to rates in 2015. The cars with zero emissions are exempted from paying registration fee, while the tax rate for PHEV in 2016 was 6 € for g CO_2/km, and in 2017 it was increased to 20 EUR g CO_2/km. The tax rates for BEV will not change. Similar reviews were made to the taxation of the commercial cars for private use, an important element in the Netherlands, taking into consideration that the sales of commercial cars had almost the same share as the sales of private cars in 2014. For BEV 4% tax rate is paid for commercial cars in private use, while the rate for PHEV was increased within 7-14% in 2015, 15-21% in 2016, and it is planned further to increase it to 22% (that is to the same rate as for conventional cars) until 2017. There is high probability that these changes in the taxation are one of the reasons for the significant downward trend in the sales of PHEV, from the record high level of 10% from the total sales of cars in 2015 to 5% in 2016. This trend continued also in the beginning of 2017, taking into consideration that even higher tax rates have been applied compared to 2016.

- The Swedish government decided to reduce the discount for buying PHEV, from 40,000 SEK (4,500 USD) in 2015 to 20,000 (2,250 USD) in 2016 (for BEV it is maintained on the level of 40,000 SEK (4,500 USD) introduced in 2011). This matches the high increase in the sales of PHEV in 2016 compared to 2015 (86%), while the sales of BEV remain stable. The growth in the sales of PHEV besides the significant reduction of the incentives for buying them, may be due to the large number of PHEV being sold as commercial cars and the incentives which arise from the reduction of the value of "additional benefits" permitted for plug-in cars in comparison to cars from the same class (the assessed saving is 1,000 SEK or 110 USD or even more per month). Besides this, the bigger offer of models of PHEV in the past several years, such as the plug-in Volkswagen Passat, Mitsubishi Outlander and plug-in Volvo V60, probably also influenced the interest of the consumers.
- Denmark began gradually to introduce taxes for registration of electric vehicles in 2016, after they were completely exempted for several years. In 2016, electric cars paid 20% of the total registration fee which is normally applied on conventional cars. This rate will be applicable for the following 5,000 sold electric cars or by the end of 2018. It will continue to grow until 2022, when full tax rate for electric cars will be applied. In parallel to this, Denmark, which was the leader in the initiatives for electrification of transport since 2008, mainly through the programs for public procurement supported by the Government, it stopped these activities in 2016. These two factors, most probably, are the main drivers for the reduced sales of electric cars (-68%) noticed since 2016. Since 2017, Denmark will introduce payment of taxes for buying electric cars based on the capacity of the battery, amounting to 225 USD/kWh, which will be applied up to the maximum capacity of 45 kWh, which is 10,000 USD.

Taxes in the Transport Sector

Taxes in the transport sector may be introduced at different points in the transport system, depending whether the objective is to influence the selection of vehicles or drivers' behavior, although both reasons can contribute to a broader objective that is to the reduction of carbon emissions from the transport sector. There are three key segments for taxation which can influence the decisions of the consumer:

- environmental tax at the initial purchase of the vehicle;
- environmental tax at registration and
- tax for using the vehicle (such as fuel tax, pay toll and parking fees).

Purchase taxes will have big influence on the selection of vehicles and depending on their design, they may impact the selection of technology and the fuel used. Registration taxes, although they do not specifically relate to the purchase, they also influence the selection of vehicles, instead of their use. Taxes affecting different aspects of the use of the vehicles (fuel taxes, fees for using roads and parking fees) have the strongest influence on the use of vehicles after they are bought. Hence, these are the main taxes used for managing the needs of the transport sector. The transport needs depend on several factors which all together determine the total level of travel. These factors are: total number of trips, length of the trip, mode of transport used and also the number of people in the vehicle. Policies aimed at reducing the congestion, as well as the level of travel, also should take into consideration the location and the time of travel. In the last decade, most of the developed countries introduced reforms in the current taxation of the road transport in order to meet the set road transport targets. These reforms included changes in the taxes in the three key segments in order to promote the following:

- Vehicles with more efficient use of fuel,
- Vehicles with alternative fuel,
- Use of cleaner fuels (low carbon and/or other emissions),
- Changing the mode of transport, and with that the level of traffic,
- Reducing the traffic congestion.

Generally, by analyzing the role of taxation in transport, we have to admit that some important taxation measures are primarily introduced in order to influence the selection of technology in the car, the type of fuel used and its consumption. However, if we want to influence the needs in the transport sector, then we have to apply a comprehensive approach to cover all components.

Some fiscal instruments applied in the European countries in order to promote sustainable transport are summarized in the following table.

Table 2. Fiscal policy instruments for sustainable transport

Type of instrument	Application of the instrument
Fuel tax	- Tax on petrol/diesel (e.g. Poland) - Carbon emission tax (e.g. Sweden)
Vehicle tax	- Annual taxes and fees paid in accordance with the vehicle performance (EU) - Reduction of taxes and fees or total exemption for new, clean, more efficient cars (e.g. Denmark, Germany, the Netherlands) - Subsidies for disposal of old vehicles (e.g. Italy) - Annual fees for CO_2 emissions and for smog (e.g. Denmark, Great Britain) - Import taxes (e.g. Romania, Bulgaria and Lithuania)
Airplane fees/taxes	- Emission taxes on landing (e.g. Sweden) - Air traffic tax (e.g. Austria, Bulgaria)
Road fees/taxes	- Congestion cost (e.g. Great Britain) - Highways with electric pay tolls (e.g. Austria, Germany, Czech Republic) - Road tax (e.g. Bulgaria, Slovak Republic)
Charges per user	- Parking fees (e.g. Austria, Finland) - Parking fees (e.g. Germany)
Subsidies for new vehicles	- „feebate“: variable tax paid when buying the vehicle depending on its fuel consumption (e.g. Austria)

Car insurance	- Penalties if there is no compulsory insurance (Great Britain, Denmark) - Specific car insurance tax (e.g. France, Austria) - Pay-as-you drive and pay-as-you pump insurance) (e.g. Great Britain)
Subsidies for the car stock	- Subsidies for clean official vehicles with efficient fuel consumption (e.g. Great Britain)

Taken from: GREEN POLICIES IN THE EU: A REVIEW
http://ec.europa.eu/social/BlobServlet?docId=7246&langId=en)

The summary of various taxation measures in the transport sector introduced in the European countries aimed at reducing CO_2 emissions is presented in Annex I – Taxes for Motor Vehicles in the EU.

The Situation of the Transport Sector in Macedonia

The transport category in the last few years has seen a growing trend of energy consumption. Namely, in Macedonia in the Energy sector, the share of transport in final consumption has increased from 24% in 2012 to 32.5% in 2015. Out of the three subcategories (road, railway and air transport), the most dominant is road transport with 97% participation in the final energy consumption.

The composition of passenger motor vehicles according to the type of vehicles, fuel they use and year of production, as per the statistic records for 2015 for Macedonia is presented in Figure 3. We can notice that the biggest share in the total passenger motor vehicles are the passenger cars - 87%, which actually are the object of this Study. Concerning the type of fuel, the most dominant fuels are petrol (51%) and transport diesel (46%). Additionally, it can be noticed that 65% of the vehicles in Macedonia are manufactured before 2002.

It is interesting that in the period between 2011 and 2015 the number of passenger cars in Macedonia has increased for 22,5% (Figure 4) which is mostly due to the permitted import of used vehicles.

The prices of the most dominant fuels used in the transport sector in Macedonia in the period between 2011 and 2015 are presented in Figure 5. It can be noticed that petrol and diesel fuels are following the same pattern (based mainly on the price of crude oil on the global market), but the diesel fuel is significantly lower in price compared to petrol. Namely, diesel fuel is generally for 15% cheaper than petrol – Eurosuper 98, and this difference was increased at the end of 2015, reaching even 30% difference in price.

In accordance with the fuel consumption, the transport sector contributed with 13% to the total national emissions in 2014, and with 20.5% in the total emissions of the Energy Sector. In the most recent years we can see a growing trend in the emissions from this category, so in 2014 emissions are for 3.6% higher than in 2013 and for 16.4% higher in comparison to 2012. Taking into consideration that road transport is the biggest source of GHG emissions (almost 99%) from the transport sector, measures and policies for emission reduction should be mostly focused on this type of transport.

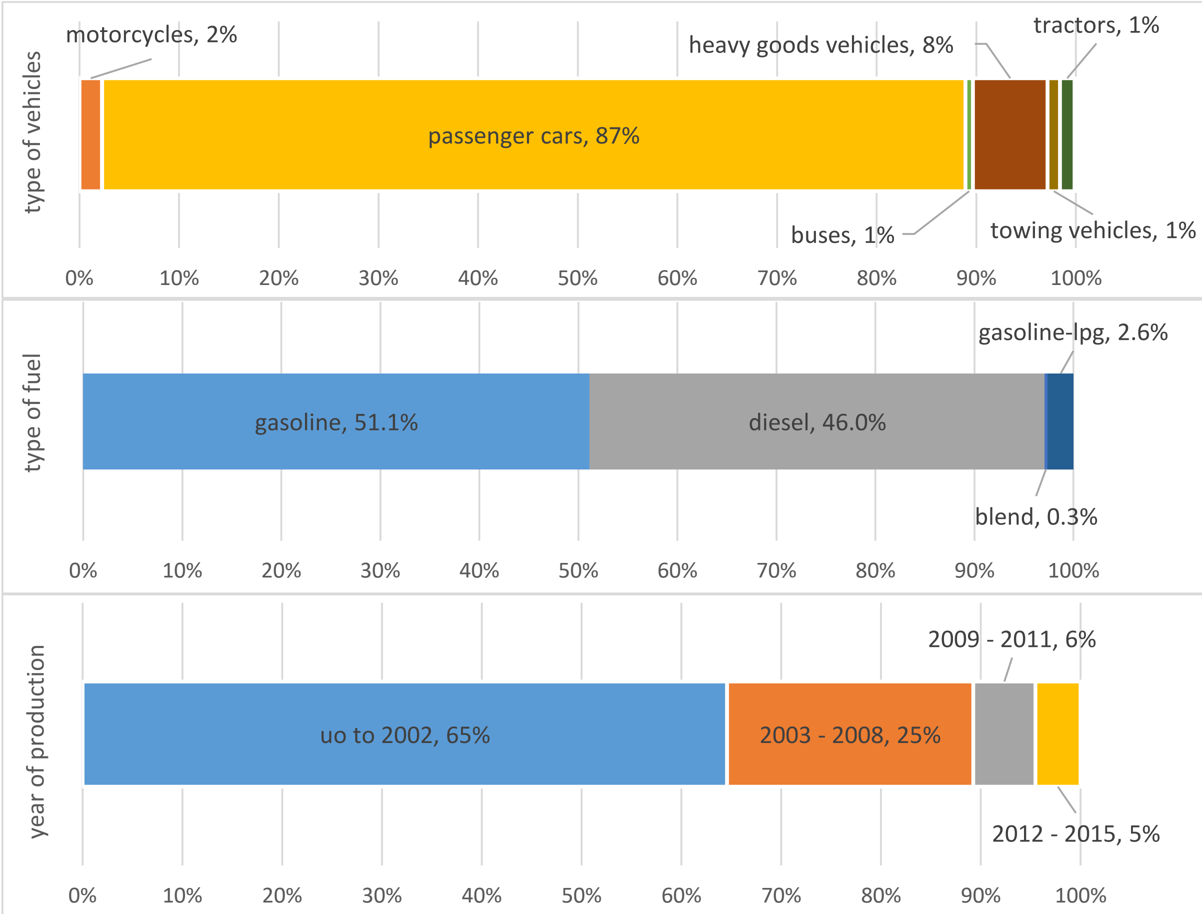


Figure 3. Composition of passenger motor vehicles against the type, fuel and year of manufacturing, as recorded at the end of 2015

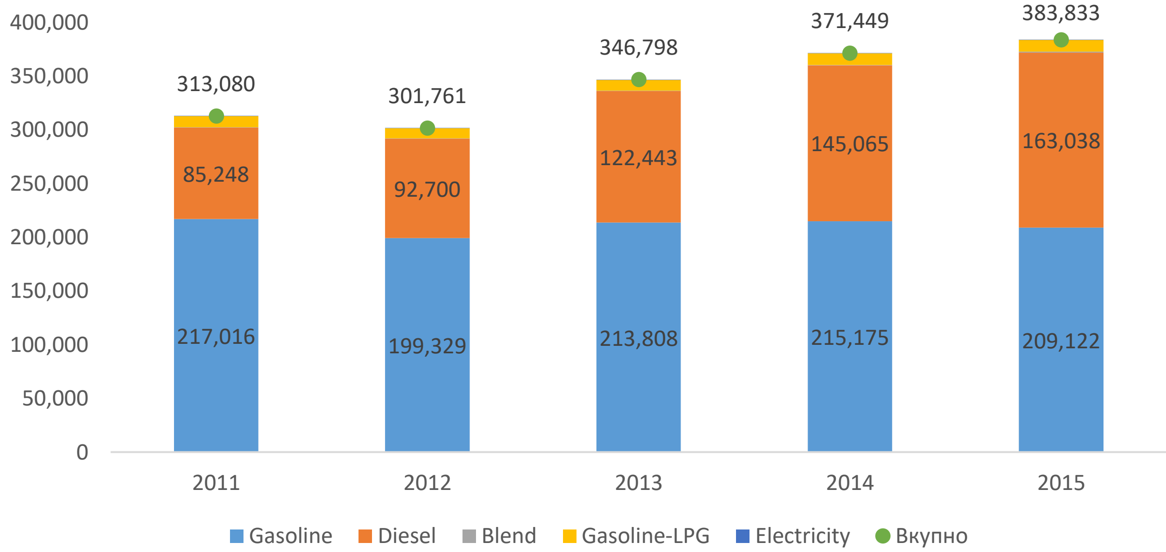


Figure 4. Number of passenger vehicles in Macedonia

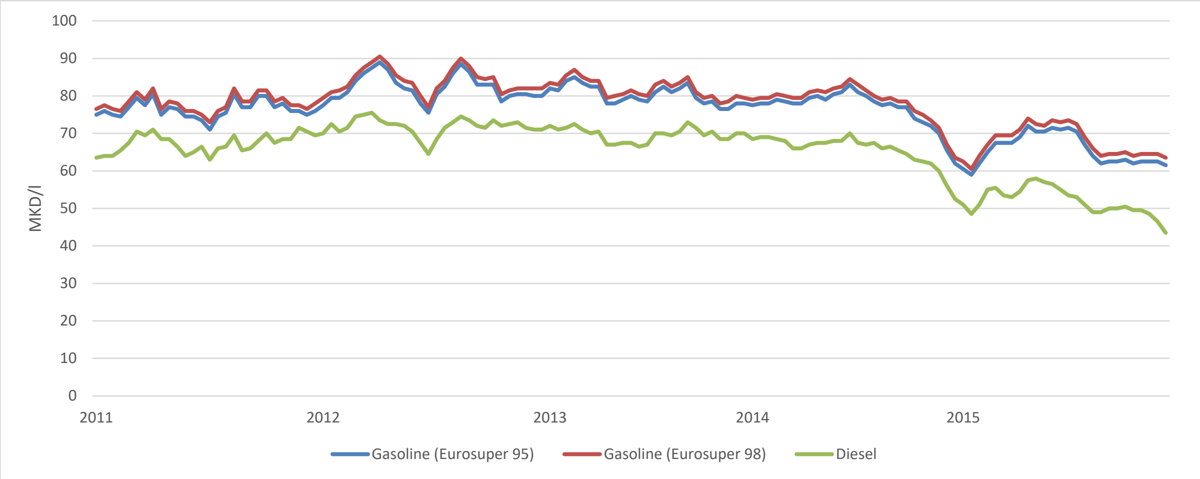


Figure 5. The highest retail prices of various oil derivates in Macedonia

Taxes in the Transport Sector in Macedonia

Just as everywhere in the world, in Macedonia transport taxes may be introduced at different points in the transport system, depending on the objective (whether it is to influence the selection of the vehicle or the behavior of the drivers). Currently in Macedonia there are fees which are paid for buying and using passenger motor vehicles and are environment related. These fees are paid:

- When importing a vehicle
- When registering a vehicle
- When pumping fuel

When importing a vehicle

When **importing passenger motor vehicles**, the following taxes are paid:

- Customs duty – 5%;
- Excise tax calculated according the value of the vehicle;
- Environmental tax - which is imposed only on used passenger motor vehicles; and
- VAT – 18%

At this, we need to have in mind that the amount of the transaction value is amended with the transport and insurance cost incurred until the vehicle enters the Republic of Macedonia.

The **excise duty,** for passenger cars is calculated based on the following:

- sale price, that is the price without the VAT or
- at import - customs value determined as per customs regulations increased with the customs duty.

The excise duty paid is determined based on the value of the passenger car in accordance with the following Table 3.

Table 3. Excise duty paid when importing passenger motor vehicles in Macedonia

Value of the passenger car [€]		Excise rate
More than	To	
0	3,000	0.00%
3,000	4,000	0.50%
4,000	5,000	1.00%
5,000	6,000	1.50%
6,000	8,500	2.00%
8,500	12,000	3.00%
12,000	14,000	4.00%
14,000	16,000	6.00%
16,000	18,000	9.00%
18,000	22,000	11.50%
22,000	25,000	13.50%
25,000	30,000	15.50%
30,000		18.00%

At this, we need to underline that passenger cars on **hybrid** drive (combination of internal combustion engine and electric motor) are exempted from paying excise duty.

Environmental tax paid only for used passenger cars, depends on the volume of the cylinder and the type of engine and is between 1500 and 3500 MKD. Actually, this tax, for used passenger cars mostly constructed for transport of people is calculated in accordance with the following Table 4.

Table 4. Environmental tax paid when importing passenger motor vehicles in Macedonia

	Cylinder volume [cm^3]	Environmental tax [MKD]
With internal combustion piston engine (besides the rotational piston engine) and ignition with spark plugs	< 1000	1500
	1000 - 3000	2000
	> 3000	3500
With internal combustion piston engine, ignition by compression (diesel and semi-diesel)	< 1500	2500
	1500-2500	3000
	> 2500	3500

When registering a vehicle

When **registering a vehicle,** once a year**,** another fee is also paid by national and foreign companies and individuals who pollute the environment by using motor vehicles. In essence, the amount determined at the registration of the vehicle consists of a fixed amount, a fee paid into the Road Fund, utility tax and environmental tax. The environmental tax paid by the owners of passenger motor vehicles is presented in Table 5.

Table 5. Environmental tax paid at the registration of vehicles in Macedonia

Engine power [kW]	Tax [MKD]
To 22	70
From 22 to 33	90
From 33 to 44	100
From 44 to 55	110
From 55 to 66	130
From 66 to 84	150
From 84 to 100	170
More or equal to 100	210

When pumping fuel

The environmental tax which is paid at the purchase of **fuel,** is stipulated in all decisions issued by the Energy Regulatory Commission of the Republic of Macedonia on the highest prices of specific oil derivates. In accordance with these decisions, and based on the fee paid for funding the environmental activities in accordance with the Law on Environment, the fuel tax depends on the type of the fuel:

- For motor petrol it is 0.08 MKD/liter
- For diesel fuel it is 0.03 MKD/liter

These amounts have not been changed since 2005.

Entry Data and Basic Assumptions

The modeling made in this Study was based on entry data and scenarios (reference scenario, mitigation scenario and more ambitious mitigation scenario) developed during the preparation of the Second Biennial Update Report on Climate Change with the assistance of the MARKAL model (the methodology for the operation of the MARKAL model is given in Annex II). Additionally to the modeling made in the MARKAL model for the SBUR, for the needs of this Study we have modeled also all environmental taxes paid in Macedonia, and we have also modelled the new proposed taxes and subsidies described further bellow in the text (Chapter - Impact Assessment).

The penetration of PHEV, BEV and the hybrid vehicles with diesel engine (as newest technology), is modelled having in mind the assumption that they will develop in accordance with the „S" curve, taking into consideration the experiences from other states (Figure 6).

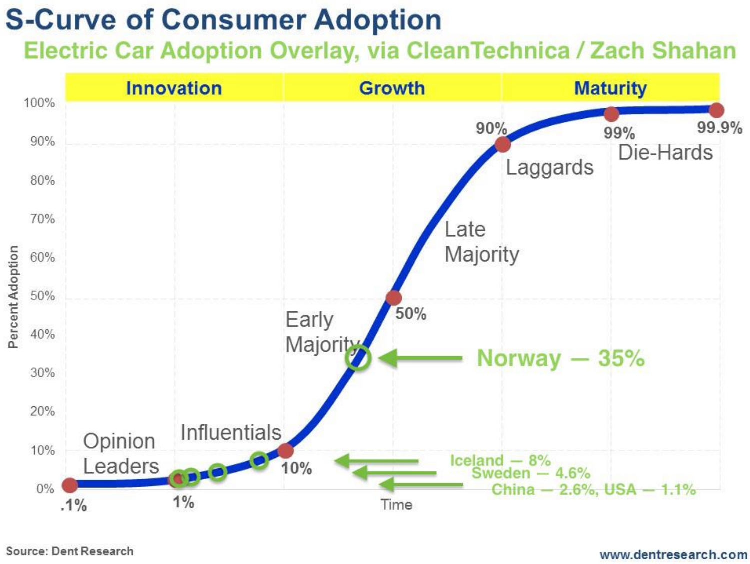


Figure 6. "S" curve of the penetration of the electric vehicles in different states

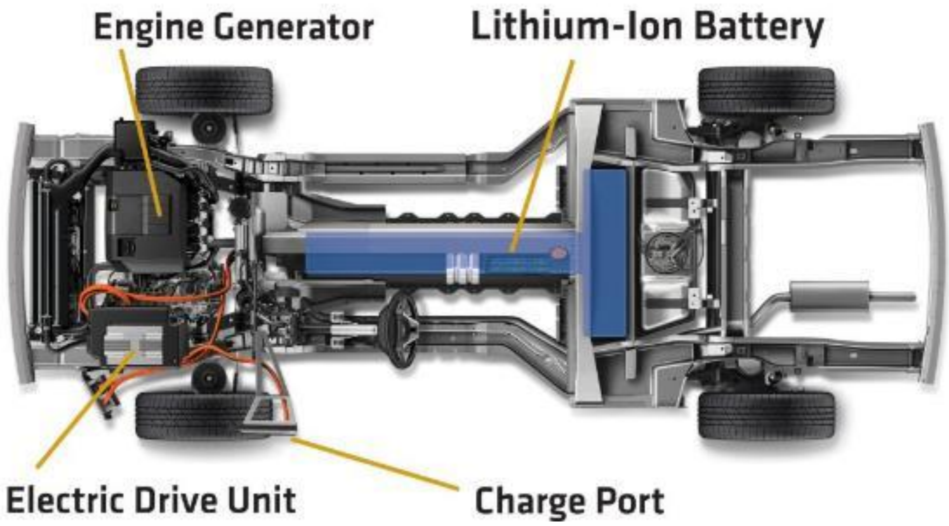
The analysis of the influence of electric cars on the penetration of renewable energy sources for the production of electricity, requires the modeling to be made on hourly level. In order to do this, the results acquired with the assistance of the MARKAL model are entered in the EnergyPlan model. Besides this, it is necessary in the EnergyPLAN model to enter the production of electricity from hydropower plants on hourly level, for which we have used the data from the daily information published by MEPSO AD. The distribution curve with hourly resolution for the wind was developed by using the hourly values for wind speed, provided by the METEONORM[7] program and the obtained hourly values from the wind park Bogdanci. The distribution curve with

[7] „Global meteorological database for engineers, planners and education," Tech. Rep., METEONORM

hourly resolution of solar energy was created with the assistance of the model Collares-Pereira and Rabl [8] and the daily data for solar radiation taken from the NASA database[9].

In the scenarios we have used vehicles with battery capacity of 70kWh and 85 kWh, as this are batteries used by the most powerful manufacturer of long range electric vehicles, Tesla[10]. In order electric vehicles to achieve the inserted percentage share of the total number of vehicles, they will have to be long range and currently Tesla is setting the standard for this type of vehicles. According to initial data, the rate of degradation of battery is less than expected (Tesla primarily assumed 30% of degradation of the battery after 160,000 km), the data shows that the degradation is close to 15 - 20%[11].

Even in hours of highest load, the analysis made[12] showed that more than 80% of the vehicles were left in the garages, and in the case of electric vehicles, they are connected to the grid, which leaves more than enough capacity for balancing the system. Some electric vehicles already have a smart charger which can be set to charge the vehicle at the lowest tarrif in agreement with the sygnals of the electicity supply grid. This system can easily be extended further on to serve as a basis for starting the procedure for stabilization of the grid and could be used for storing the surplus of energy present in the grid, but also if needed it can be used to withdraw energy from the battery, that is to use it to power the grid. The user will decide for how long the car will be available for balancing the system, and this will also be subsidized.



For the needs of this Study we have assumed that maximum 20% of electric vehicles will be charged during the time of highest load (consumption) during the day. Also, it is assumed that maximum 70% of the parked electric cars will be connected to the grid. Additionally, the charging efficiency, that is the conversion of electricity from the grid into the battery is assumed to be 90%. Concerning the use of the cars, we have introduced a curve for 8784 hours, by which we assume

[8] M. Collares-Pereira, A. Rabl, Solar Energy 22, 155, (1979)
[9] „Nasa surface meteorology and solar energy: Daily averaged data, https://eosweb.larc.nasa.govcgi-binssedaily.cgi?email=skip@larc.nasa.gov"
[10] http://www.teslamotors.com/
[11] T. Saxton, „Plug in americas tesla roadster battery study," Tech. Rep., Plug In America (2013)
[12] W. Kempton, J. Tomic, S. Letendre, A. Brooks, T. Lipman, Inst. Transp. Stud. (2001)

that during the day cars are parked from midnight to 7 AM, then from 8 AM to 7 PM they are moving and also from 8 PM to midnight they are parked.

Reference Scenario

In order to determine to what degree certain policy of measure will contribute for the reduction of GHG emissions, first a **Reference scenario** or Without Measures Scenario **(WOM)** was developed. This scenario actually does not foresee some of the changes in technologies which are used on the demand side, which means that technologies that will be used by 2035 and will have the same characteristics as those technologies used in 2012, **which could not happen in reality**. However, this scenario **is of crucial importance** in order to compare all policies and measures with the same reference option and to determine the impact of those policies and measures (financial, energy related, environmental). Taking into consideration that some of the measures and policies analyzed in this study have ross-sectoral influence, as for e.g. the introduction of electric vehicles which will also impact the electricity production sector, the reference scenario needs to be developed for the whole energy production system. In order to do this, in this Study we have used the Reference scenario from the Second Biennial Update Report on Climate Change.

Reductions in the prices of oil derivates on global level in the period between 2012 and 2015, and especially in 2016, caused the consumption in the sector to grow with a growth rate higher than projected, and this is true not only for the Republic of Macedonia, but also on global scale. If we add to this the effect of the policies for importing used vehicles of the Government of the Republic of Macedonia, we will see that the state in the transport sector of Macedonia has significantly changed. In order the MARKAL model to reflect this new situation, besides revising the data on the oil derivates, we have also completely revised the number of vehicles (new and used) bought in the Republic of Macedonia, the average number of kilometers driven, the average number of tones transported etc.

In order to calculate the consumption of energy in the transport sector, especially by passenger cars, in the MARKAL model we have entered the projections for passenger-kilometers which were obtained as a result of the growing GDP. In the period until 2035, it is projected that the passenger-kilometers will increase for 120% compared to 2012 or for 75.5% compared to 2015. Passenger cars will have the biggest share in passenger-kilometers, namely 79.5% which is almost for 20% more compared to their share in 2012 (58.5%) (Figure 7). This increase is mostly a result of the increased number of passenger cars in Macedonia, which has a much lower motorization level in comparison to EU member-states (EU (28)). For the sake of comparison, in 2015 in Macedonia there were about 190 passenger cars to 1000 inhabitants (about 150 passenger cars to 1000 inhabitants in 2012), while in the EU (28) this number is close to 500 passenger cars to 1000 inhabitants, which actually means that every second inhabitant in the European Union uses passenger car, while in Macedonia every fifth inhabitant uses a passenger car.

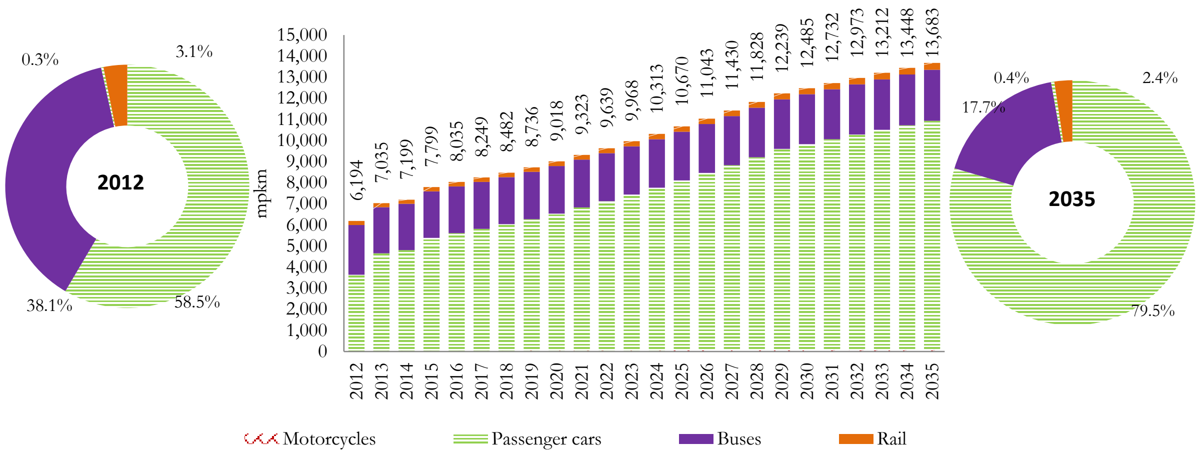


Figure 7. Projections about passenger-kilometers in Macedonia

Energy Consumption

Based on the projections made concerning the needs of useful energy and having in mind the technologies which would be available in 2012 in the Republic of Macedonia in all sectors on the demand side, the MARKAL model, based on the lowest price, determines the final energy consumption until 2035 (Figure 8). The results obtained point to the following:

- Increase of **91%** in 2035 compared to 2012, that is from **1,830 ktoe** to **3,497 ktoe**;
- Continuous dominant presence of **oil derivates** throughout the whole period **of about 40%**;
- The transport is **the third sector** by its share in the total final consumption, with almost **30% in 2012**, that is **27% in 2035**;
- Although the share in 2035 (26.7%) is lower than in 2012 (29.9%), in absoulte numbers there is an increase in the consumption in transport sector for 113% in 2035 (946 ktoe) compared to 2012 (444 ktoe).

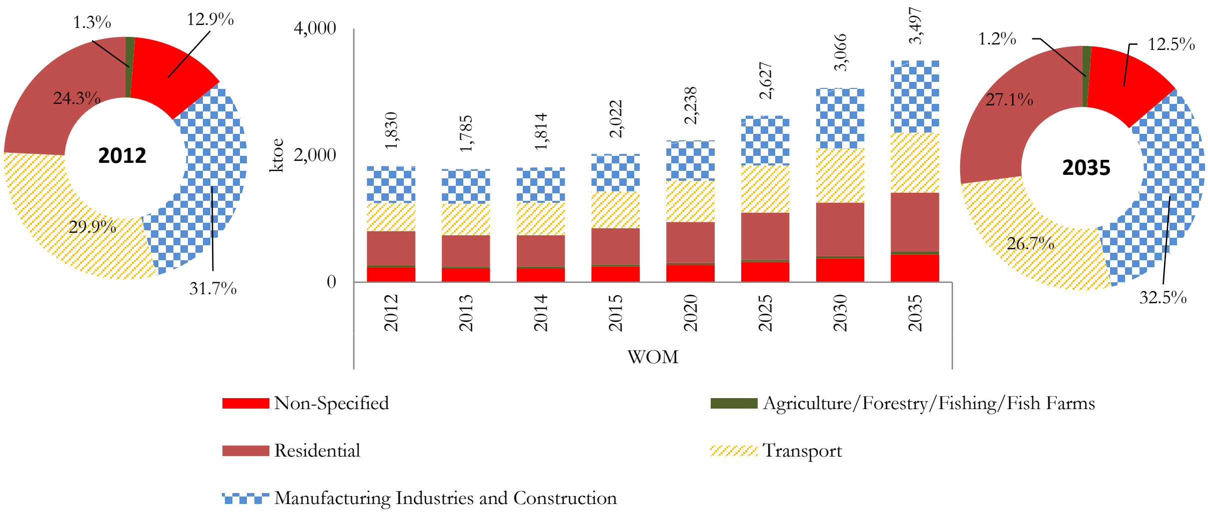


Figure 8. Final energy consumption per sector (in ktoe) - Reference scenario

Electricity Production

Electricity production is also an important segment of this Study, especially because one of the measures/policies analyzed is the electrification of transport. The Reference scenario predicts electricity mainly to be produced from fossil fuels, which is actually the main reason for high contribution of the energy sector in the GHG emissions in the Republic of Macedonia. According to the projections in the Reference scenario (Figure 9), we obtain the following results:

- **Electricity consumption** in 2035 (8,301 GWh) will increase for **84%** compared to 2012 (15.261 GWh)
- **The coal power plants** are still the most dominant in the production of electricity (**63%,** in 2035);
- By **maximum** utilization of the existing **gas pipe-line capacity** the share of electricity produced by **thermal power plant and cogeneration power plants** will be increased (**15.5%)**;
- The share of **hydro-power plants** will be reduced from **12.4%** (2012) to **11.7%** (2035) because no new hydro-power plants are planned to be constructed;
- **The import of electricity will be** significantly reduced to **8.6%** in 2035 (compared to **32.4%** in 2012).
- In order to satisfy the needs for electricity, the total installed capacity for production of electricity will be increased for 43%, that is from 1,830 MW in 2012 to 2,627 MW in 2035.

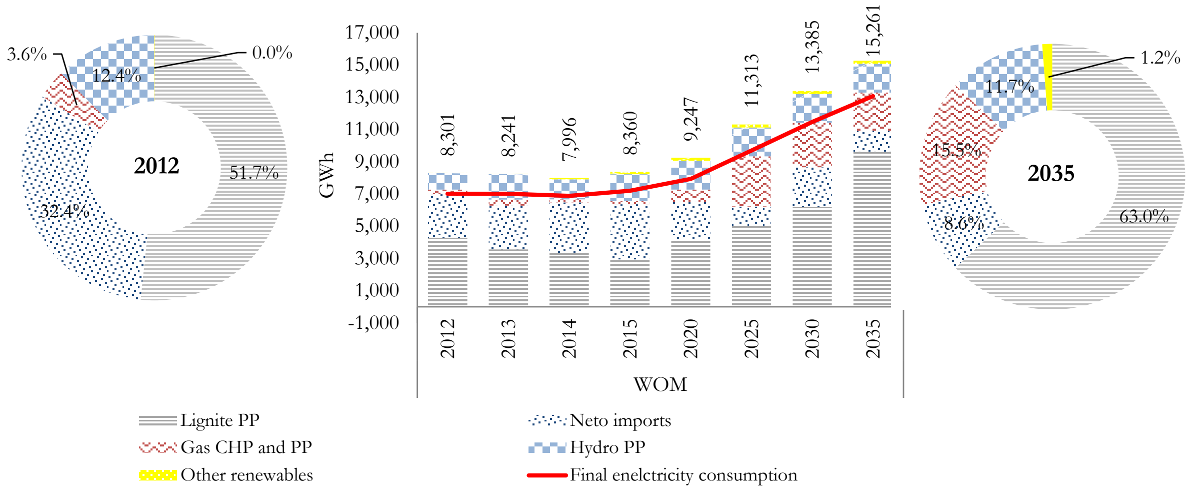


Figure 9. Electricity production (in GWh)

GHG Emissions

The increase in the total energy needs, especially the increased production of electricity from coal and gas will bring about an increase in the total GHG emissions from **11,295 Gg CO_2-eq in 2012 to 17,580 Gg CO_2-eq in 2035** or a total increase of **56%** (Figure 10).

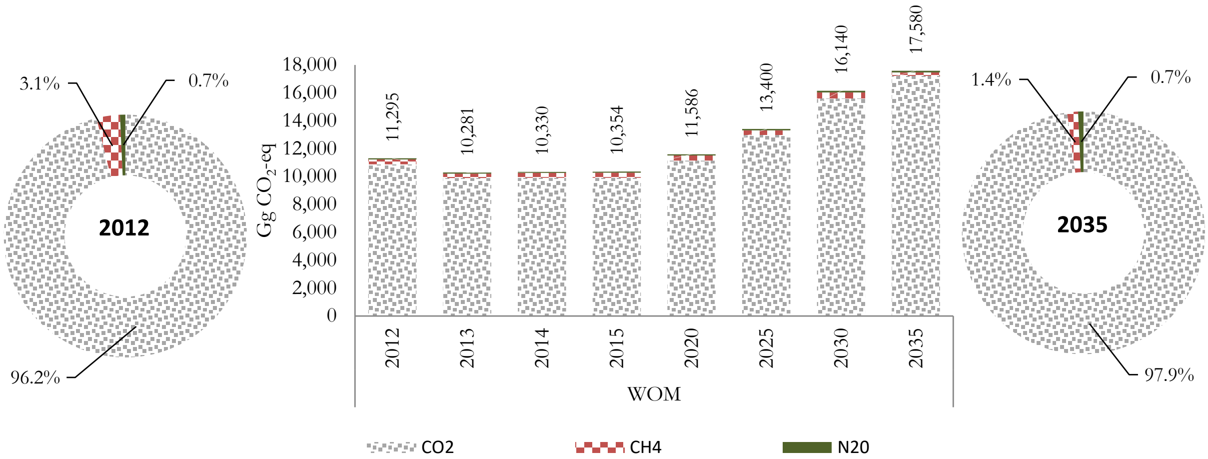


Figure 10. Total GHG emissions in the Energy Sector per gas (in Gg CO_2-eq)

Almost 98% of the total emissions in 2035 are CO_2 emissions, so by analyzing them in greater detail (Figure 11

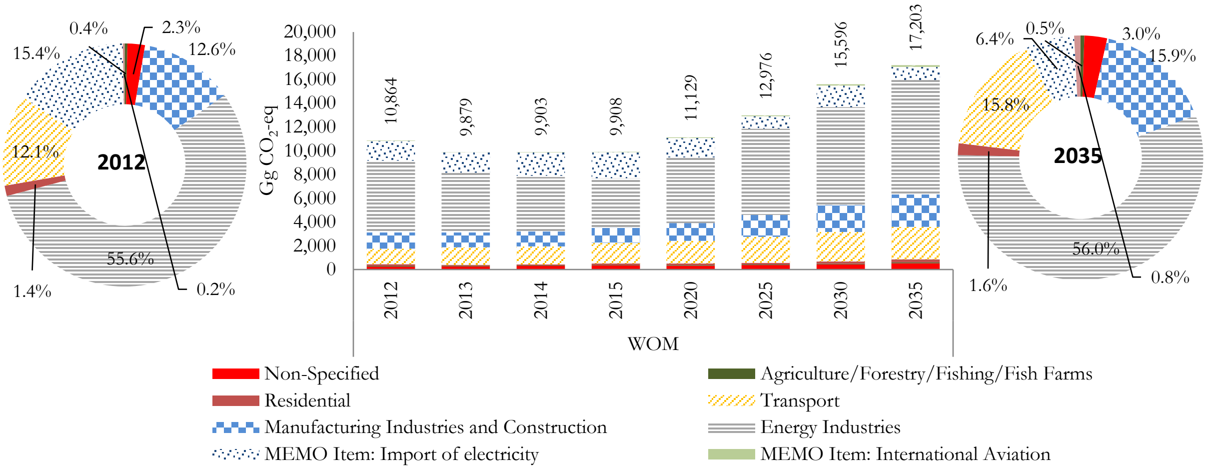


Figure 11), we can notice the following:

- Total increase of 58%, that is of 10,864 Gg CO_2-eq in 2012 to 17,203 Gg CO_2-eq in 2035
- The category transport will have an increased share from 12.1% in 2012 to 15.8% in 2035.

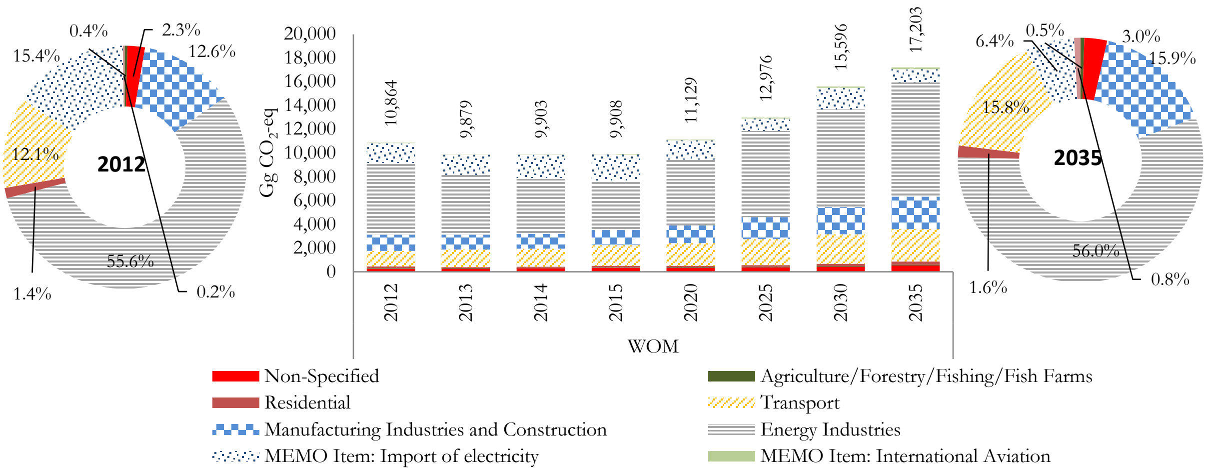


Figure 11. CO_2 emissions per sectors (in Gg CO_2-eq)

In the transport category, the biggest share of GHG emissions in 2012 is caused by the sub-categories passenger cars (40.8%) and heavy goods vehicles (39.8%). The development of the Macedonian economy will also requires the transport of goods with heavy goods vehicles and as a result of this, they will have increasingly participate in the total GHG emissions from the transport category to 46.6% in 2030. Passenger cars in 2035 are predicted to contribute with 28.2% in the total GHG emissions.

It is very important to underline that in this Study we analyze only passenger cars as a sub-category in the transport category.

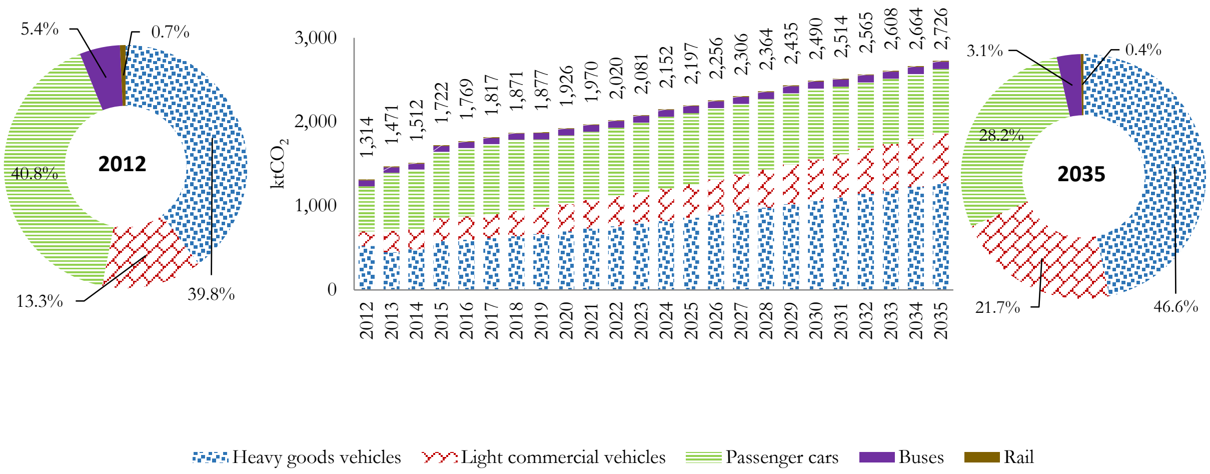


Figure 12. CO_2 emissions per category (in $ktCO_2$)

Impact Assessment

At this stage of electric cars market distribution still supporting policies are needed in order to reduce the barriers for technology adoption. Such environment with supporting policies will enable market growth by making the vehicles attractive for the consumers, it will reduce risks for investors and encourage manufacturers to invest in large-scale production capacities for electric vehicles. Especially, these factors provide for a broad offer of models for consumers, which is crucial in stimulating sales' growth. Mechanisms of the supporting policies can be grouped into four main categories: support for research & development of innovative technologies; objectives, mandates and regulations; financial incentives; and other instruments (primarily imposed in cities) in order to permit for increasing the value of electric vehicles. Public procurement (a good example to follow) is also suitable for facilitation of the penetration of electric vehicles.

Based on the analyses of the state of affairs in the transport sector in Macedonia, as well as the state of affairs on the market of electric cars in Europe and in the world, this chapter presents certain policies and measures that could define the direction of development of the transport sector in Macedonia. One can conclude that environmental taxes in Macedonia are currently based on the engine power (when registering the vehicle) and the cylinder volume (when importing used passenger vehicles). When procuring fuel, the environmental tax depends on the type of fuel, meaning that diesel fuel has more than a double lower tax compared to petrol. The excise duty paid when importing a passenger vehicle depends on the value of the vehicle, i.e. lower excise duty is paid for vehicles of lower value. In addition, it is important to highlight that hybrid-powered cars are exempted from paying excise duty.

Based on the abovementioned and taking into consideration the practices and policies of developed countries in Europe and across the globe, one can conclude that these environmental taxes could, in future, depend directly from the CO_2 emissions released from the fuel combustion, declared by the car manufacturer. The measures proposed within this study point to this direction. Namely, the following measures have been put forward towards introducing a CO_2 tax:

- The environmental tax imposed for import of used vehicles to be also valid for new vehicles and to depend on the CO_2 emissions,
- The environmental tax imposed for vehicle registration to depend on CO_2 emissions, instead of solely the vehicle engine power,
- The environmental tax for fuels to be equaled for petrol and diesel fuel, and to be increased.

The following policies are drafted as additional financial measures for promotion of low- CO_2 emission vehicles during import:

- Exemption from excise duty, not only for hybrid vehicles but also for electric vehicles,
- Cutting VAT from 18% to 5% for hybrid and electric vehicles.

One of the measures proposed is also **equaling the excise duty for diesel fuel and petrol**, similar to countries in Europe and Macedonia's surrounding area.

Environmental Tax at Vehicle Registration

This measure does not include the introduction of a new tax but changes in the methodology of calculating the existing environmental tax at vehicle registration. Namely, it is proposed the tax to depend directly on the declared value of the vehice for CO_2 emissions, which depends on the vehicle's average consumption and the type of fuel. The new methodology stipulates the division of vehicles into 15 categories, the first including those with zero emissions of CO_2/km (BEV) and the last those having emissions over 200g CO_2/km. The coefficient expressed in MKD/g CO_2/km is determined depending on the vehicle category, whereas the environmental tax is calculated by multiplying this coefficient by the declared value of the gCO_2/km for every vehicle. A three-year adaptation period is projected, during which these coefficients would gradually increase, starting from 2018.

The environmental tax at registration would cost the owners the following:

- *Battery Electric Vehicle (BEV) 0 MKD*
- *PHEV a maximum of 81 MKD*
- *Hybrid vehicles a maximum of 250 MKD*
- *An average vehicle on diesel or petrol 700 MKD*

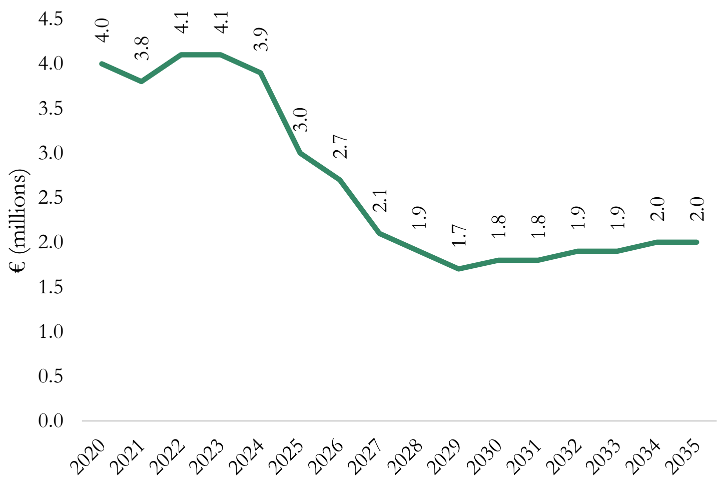
The social aspect has been taken into consideration when creating these coefficients and they are not very high if compared to European countries. Namely, the tax for hybrid vehicles in the period 2020-2035 is similar to the maximum current environmental tax (MKD 210). Table 6 gives an example of the amount of environmental taxes for each category in the period 2020-2035, assuming that declared emissions equal the upper limit of each category.

Vehicles that have no declaration over the quantity of CO_2 emissions are considered to be part of the category exceeding 300g CO_2/km.

Table 6. New environmental (CO_2) taxes at vehicle registration

Limit values of CO_2 (g CO_2/km)		Coefficient per year (MKD/g CO_2/km)			Example (MKD)
From	To	2018	2019	2020-2035	2020-2035
0	0	0.0	0.0	0.0	0
1	65	1.3	1.3	1.3	81
66	90	1.9	1.9	1.9	169
91	100	1.9	1.9	2.5	250
101	110	2.5	2.5	3.1	344
111	120	2.5	3.1	3.1	375
121	130	3.1	3.8	4.4	569
131	140	3.8	4.4	5.0	700
141	160	4.4	5.0	5.6	900
161	180	5.0	6.3	6.9	1235
181	200	5.6	6.9	8.1	1625
201	225	6.3	8.1	9.4	2109
226	250	6.9	8.8	10.6	2662
251	300	7.5	10.0	11.9	3563
301		8.1	11.3	13.8	>3563

With the application of the new methodology for calculation of the environmental tax and the use of the MARKAL model we concluded that the tax, by itself, will not result in a change of the vehicle stock in Macedonia in comparison to the Reference Scenario in the period up to 2035. However, it is of enormous importance that this environmental tax will result in the collection of significant funds that can be used for direct subsidizing of low CO_2-emission vehicles, such as hybrid and electric vehicles. Figure 13 shows the funds obtained from this tax per year. At the onset of this period, as a result of the old vehicle stock and high CO_2-emission vehicles, this amount is approximately 4 million euros. Since this is a planning period of almost 20 years, every family is supposed to replace or purchase a new vehicle that is more efficient than the existing one over the course of this period. As a result, the funds collected from this tax will reduce and will amount to approximately 2 million euros in 2035.



If one assumes that all funds collected from this tax are intended for direct subsidies of electric vehicles, i.e. 5000 euros per vehicle, subsidies can be provided for 400-800 vehicles per year.

Figure 13. Total funds collected from environmental tax at vehicle registration

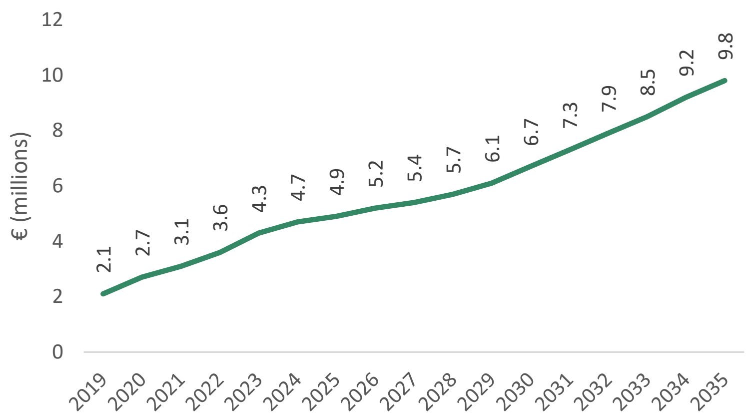
Environmental Tax on Fuels

According to the current environmental fee allocated for each liter of motor fuel (0.08MKD/liter), a person driving 10,000km a year in a car that consumes 10 liters/100km annually spends MKD 80 for environmental purposes.

According to the proposed methodology, a person driving 10,000km a year in a car that consumes 10 liters/100km shall annually spend MKD 300 in 2019 up to MKD 2,000 in 2035.

A change in the current value of the environmental fee allocated for environmental purposes per purchased liter of fuel is planned, accompanied by its equaling for all types of oil products used in the transport sector. The current 0.08 MKD/liter for petrol and 0.03 MKD/l for diesel fuel is projected to increase to MKD 0.3/l in 2018, followed by annual proportional changes, reaching MKD 2/l by 2035. Moreover, this fee is expected to also be valid for liquid petroleum gas (LPG).

The application of the new values for environmental taxes of fuels and use of the MARKAL model means that this tax, by itself, will not result in a change of the vehicle stock in Macedonia in relation to the Reference Scenario in the period up to 2035. Still, significant funds are obtained in this case, which can be used for direct subsidizing of low CO_2-emission vehicles. Figure 14 shows the annual funds obtained from this tax. At the onset, in 2019, the total funds obtained from the environmental tax of fuels amounts to approximately 2.1 million euros. The increase of this environmental tax up to 2 MKD/l in 2035 will result in an increase of the collected funds to approximately 9.8 million euros in 2035.



If assumed that all funds collected from this tax are intended for direct subsidies of electric vehicles, i.e. EUR 5,000 per vehicle, subsidies can be provided for 420-1960 vehicles per year.

Figure 14. Total funds collected from environmental tax at fuel purchase

IMPORTANT: Collected funds only refer to the section of passenger vehicles, other types of transport are not included.

Environmental Tax at Import

This measure stipulates the payment of an environmental tax at import, not only for used but also for new vehicles. It also foresees that the tax does not depend on the cylinder volume but the declared CO_2 emissions of the vehicle (which depends on the average consumption of the vehicle and the fuel type). Again, as with the environmental tax at vehicle registration, vehicles are to be divided into 15 categories, meaning that each category will have a different coefficient expressed in MKD/g CO_2/km (Table 7). Again, calculation of the total tax to be paid by a vehicle requires multiplication of the proper coefficient for that vehicle by the declared value of emissions given in gCO_2/km. A three-year adaptation period is projected, during which these coefficients will gradually increase, starting from 2018. Compared to European countries, the social aspect and standard in Macedonia has been taken into consideration when determining these coefficients. Namely, the tax for vehicles with declared emissions belonging to category 121-130g CO_2/km (this includes a vehicle using diesel fuel having declared consumption of 5l/100km or a vehicle using petrol having declared consumption of 5,7l/100km) in period 2020-2035 is similar to the maximum current environmental tax (MKD 3,500). Table 7 gives an example on the amount of environmental taxes for each category in the period 2020-2035, assuming that the declared emissions equal the upper limit of each category.

In comparison, when importing a vehicle using petrol and consuming 10l/100km, the environmental tax will amount to approximately 19,300 MKD. On the other hand, when importing a hybrid vehicle, the tax amounts to a maximum of 2,000 MKD, a maximum of 650 MKD for PHEV, and 0 MKD for BEV.

Vehicles without declaration over quantity of CO_2 emissions are to be included in category exceeding 300g CO_2/km.

Table 7. New environmental (CO_2) taxes at vehicle import

Limit values of CO_2 (g CO_2/km)		Coefficient per year (MKD/g CO_2/km)			Example (MKD)
From	To	2018	2019	2020-2035	2020-2035
0	0	0	0	0	0
1	65	10	10	10	650
66	90	15	15	15	1350
91	100	15	15	20	2000
101	110	20	20	25	2750
111	120	20	25	25	3000
121	130	25	30	35	4550
131	140	30	35	40	5600
141	160	35	40	45	7200
161	180	40	50	55	9877
181	200	45	55	65	13000
201	225	50	65	75	16875
226	250	55	70	85	21296
251	300	60	80	95	28500
301		65	90	110	>28500

The application of new values for the environmental tax at import of used and new vehicles and the use of the MARKAL model show that this tax, by itself, will not result in a change of the vehicle stock in Macedonia in relation to the Reference Scenario in the period up to 2035. Still, significant funds are obtained in this case, which can be used for direct subsidizing of low CO_2-emission vehicles. Figure 15 shows the annual funds obtained from this tax. At the onset, in 2019, the total funds obtained from the environmental tax at vehicle import amount to about 8.1 million euros. Over the course of the analyzed period of 20 years, every family is supposed to replace or purchase a new vehicle that is more efficient than the existing one. As a result, the funds collected from this tax will reduce and amount to approximately 0.3 million euros in 2035.

If assumed that all funds collected from this tax are intended for direct subsidies of electric vehicles, i.e. EUR 5,000 per vehicle, subsidies can be provided for 50-1620 vehicles per year.

Figure 15. Total funds collected from environmental tax at vehicle import

Equaling Excise Duty of Diesel Fuel and Petrol

According to the latest report of Global Petrol Prices[13] (of 25 September 2017), Macedonia is the country having the fifth-lowest price of diesel fuel in Europe, behind Russia, Belarus, Moldova and the Ukraine, and the eighth-lowest price of petrol (Figure 16). If one makes a comparison of the percentage difference between the prices of the diesel and petrol, one can perceive that the difference is currently almost 23%, i.e. diesel fuel is by 23% cheaper than petrol. This difference varies from one country to another, for example:

- Diesel fuel in Serbia is more expensive than petrol by 3.4%,
- Prices of diesel fuel and petrol are the same in Albania,
- Diesel fuel in Bulgaria is cheaper than petrol by 1%,
- Diesel fuel in Croatia is cheaper by 8.7% than petrol,
- Diesel fuel in Slovenia is cheaper by 4.7% than petrol.

This difference in Macedonia is largest primarily due to the lower excise duty paid on diesel fuel. According to the latest decision of the Energy Regulatory Commission of the Republic of Macedonia (18 September 2017), the excise duty amounts to 12.15 MKD/liter for diesel fuel and approximately 22 MKD/liter for petrol (Unleaded-95 22 MKD/liter, Unleaded-98 21.73 MKD/liter).

This study predicts equaling the excise duties of diesel fuel and petrol. This equaling would be carried out gradually up to 2025, when excise duty for all oil products should be equal. The equalization process is to begin in 2018.

[13] http://www.globalpetrolprices.com/

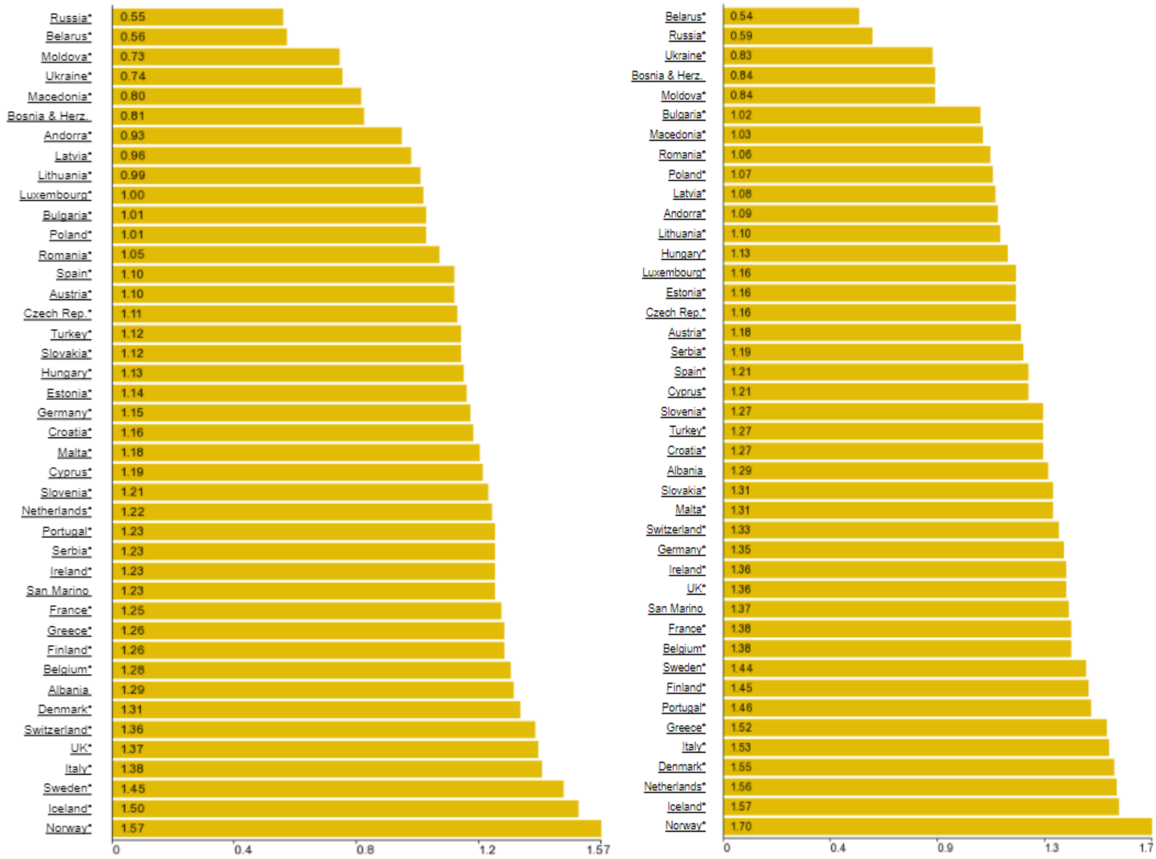


Figure 16. Sales prices of diesel fuel (left) and petrol (right) in Europe (according to Global Petrol Prices)

As a result of the equalization of the diesel fuel and petrol excise duties, the purchase of used diesel vehicles beyond 2023 will no longer be profitable (Figure 17). Instead of used diesel vehicles it will be more profitable to buy new diesel vehicles and petrol vehicles. Furthermore, a certain number of new diesel vehicles in the Reference Scenario will be replaced by new petrol vehicles in the period beyond 2029.

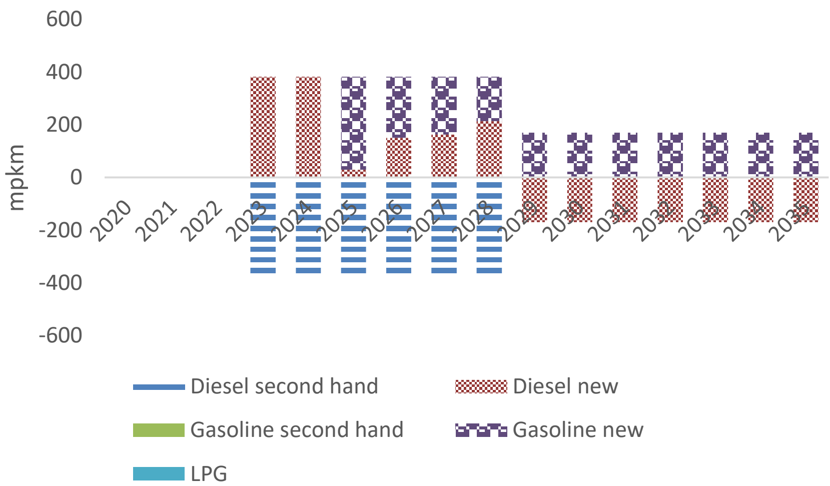


Figure 17. Difference in passenger km through application of the measure for equalization of the diesel fuel and petrol excise duties compared to the Reference Scenario

Reducing Excise Duty and VAT at Vehicle Import

There are a number of ways that can enable increased integration of hybrid and electric vehicles in the transport sector. Some are described through the previous four measures, but they are small by themselves, and additional mechanisms need to be found as a result. The biggest problem regarding the current low share of these vehicles is their high price compared to conventional vehicles. One of the mechanisms for greater share is indirect subsidizing, through reducing the excise duty at import and reducing the Value Added Tax (VAT).

This study analyses the effect of the current policy for cancelling the excise duty at import of hybrid vehicles and cutting the VAT from 18% to 5% not only for hybrid vehicles but also for electric ones.

The results of the measure are the following:

- Drop in purchasing of used diesel cars starting from 2019, replaced by the purchase of hybrid vehicles using petrol (Figure 18),
- As of 2021, purchasing of hybrid cars using petrol and hybrid diesel cars (Figure 18) instead of purchasing used cars using petrol and new diesel cars (Reference Scenario),
- Lowering of CO_2 emissions by 10% in 2035 in relation to the section of passenger cars in the Reference Scenario.

Enabling a larger penetration of hybrid vehicles is obviously good from the aspect of energy efficiency and lowering of GHG emissions. On the other hand, they are, in a way, a transition technology, i.e. predecessor of the electric vehicles. Taking into consideration that hybrid vehicles will spread quite slowly according to the common market rules because they are more expensive than conventional cars, but also maintain their value for a longer period as used vehicles, it is necessary to subsidize the initial market penetration. Results have shown the necessity of only indirect subsidizing through cancellation of the excise duty and cutting of VAT without any additional direct subsidizing. It is necessary to find a mechanism of validating indirect subsidizing only for high-efficient hybrid vehicles, having emissions less than 90 gCO_2/km, thus avoiding subsidizing of expensive cars where the hybrid technology is there more for the purpose of luxury than vehicle efficiency, which would be inappropriate from a social viewpoint.

As seen in Figure 18, there is no penetration of electric cars because cancellation of the excise duty and cutting of the VAT is not sufficient for them to be competitive at the market.

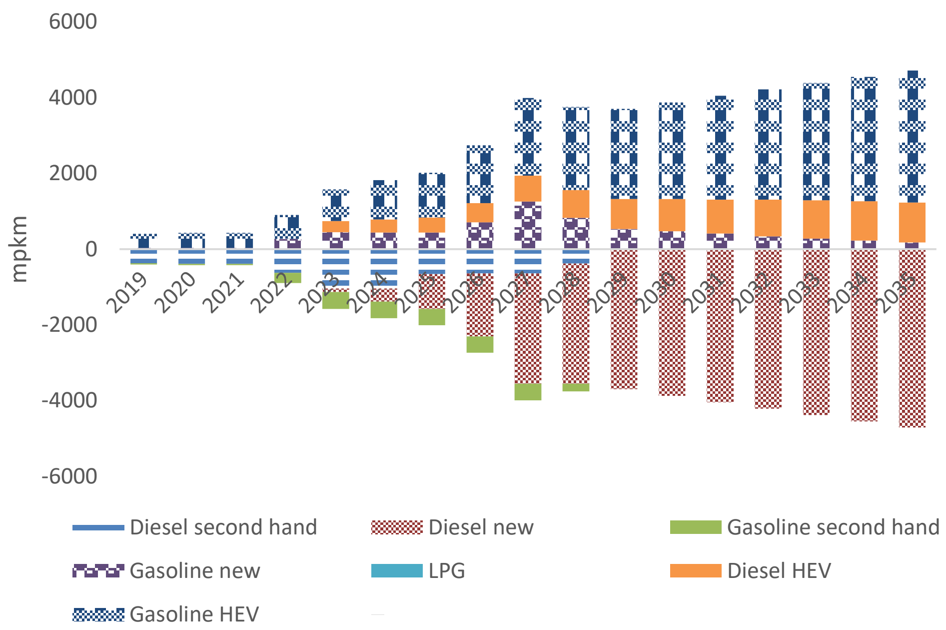


Figure 18. Difference in passenger km by applying the measure of reducing excise duty and VAT at vehicle import in relation to Reference Scenario

Subsidies for Electric Cars

For the purpose of making electric cars more competitive at the market and to enable their penetration, this study analyzes two cases:

1. Direct subsidizing,
2. Cancelling excise duty and cutting VAT from 18% to 5% at import and additional direct subsidizing.

The first case involves direct subsidies of 10,000 euros for every purchased new Battery Electric Vehicle (BEV) and 7,000 euros for every purchased new Plug-in Hybrid Electric Vehicle (PHEV). Results show the following:

- The sole introduction of direct subsidies would make electric cars competitive in 2026 and replace new diesel vehicles purchased in the Reference Scenario (Figure 19),
- Approximately 2,000 mpkm that are served by new diesel vehicles will be replaced by electric vehicles in 2035 (Figure 19),
- Share of electric vehicles in the total mpkm in 2035 would amount to approximately 19% (11.3% BEV and 8% PHEV),
- Cutting of CO_2 emissions in 2035 by 14% in relation to the section of passenger cars in the Reference Scenario.

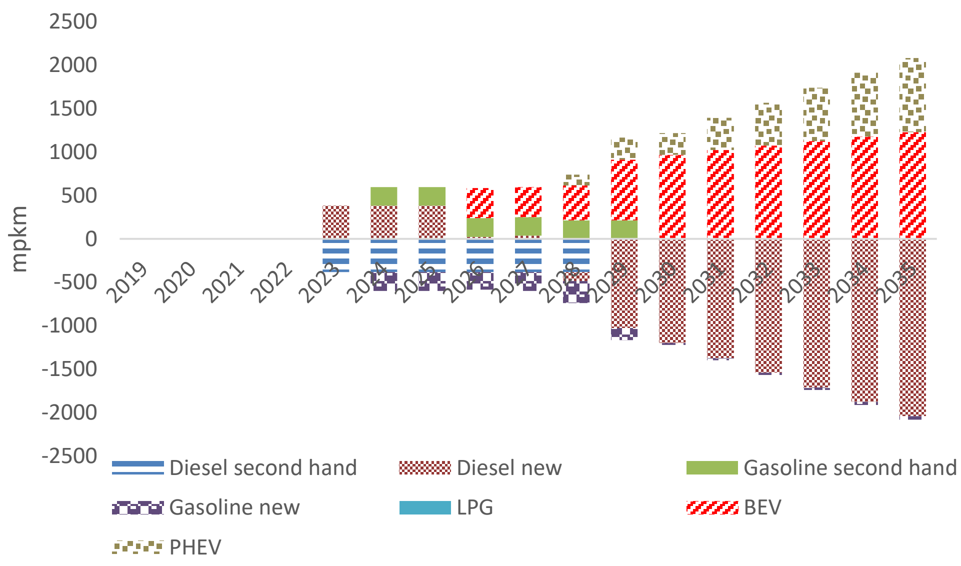


Figure 19. Difference in passenger km by applying measure direct subsidies for electric vehicles in relation to Reference Scenario

In the second case, the outcomes from the introduction of mechanism of direct and indirect subsidizing were analyzed, i.e. direct subsidies besides the cancelling of excise duties and cutting of VAT from 18% to 5%.

A sensitivity analysis was carried out in this section, which showed the following:

- Direct subsidies in this case are far lower compared to the first case where only direct subsidies are provided (Figure 20),
- Direct subsidies would be variable over the course of the entire period, starting from 7,000 euros for BEV in 2019, gradually dropping to 3,500 euros in 2035, whereas starting from 3,500 euros and dropping to 1,500 euros for PHEV (Figure 20),
- The penetration of electric vehicles begins in 2019 (Figure 20),
- Approximately 3,000 mpm served by new diesel vehicles in the Reference Scenario will be replaced by electric vehicles in 2035 (Figure 20),
- The share of electric vehicles in the total mpkm would amount to approximately 25% (12.5% BEV and 12.5% PHEV) (Figure 20),
- Lowering of CO_2 emissions by 17% in 2035 in relation to the passenger car section in the Reference Scenario.

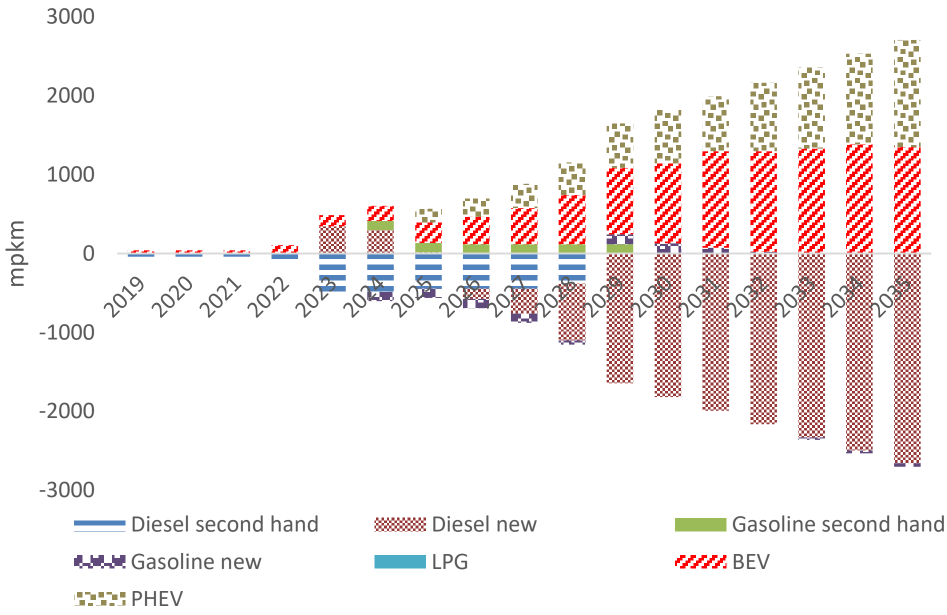


Figure 20. Difference in passenger km by applying the measure of cancelling the excise duty and reducing VAT from 18% to 5% at import and additional direct subsidizing in relation to the Reference Scenario

"Green & Smart" Scenario

In conclusion to the previously elaborated measures, each measure cannot contribute much by itself for the introduction of low-carbon vehicles in the Republic of Macedonia. Therefore, more measures need to be simultaneously implemented in order to secure a gradual de-carbonization of the transport sector, which is the area where reducing GHG emissions is most difficult to achieve. For this purpose, this study has created a scenario "Green & Smart" where all previously elaborated measures are jointly implemented. This scenario produces the following:

- A gradual penetration of hybrid and electric vehicles is projected as of 2019,
- Drop in the share of hybrid vehicles and their replacement with PHEV in the period beyond 2026 (Figure 21),
- Share of hybrid vehicles in the total mpkm in 2035 would amount to 25.9% (18.8% petrol and 7.1% diesel) (Figure 21),
- Share of electric vehicles in the total mpkm in 2035 would amount to 40.8% (24.7% BEV and 16.1% PHEV) (Figure 21),
- Approximately 40% share of BEV in the total number of vehicles in 2035, which is primarily due to the fact that 80% of vehicles used for city driving in 2035 are projected as electric, while the remaining 20% as hybrid (Figure 22),
- Reducing GHG emissions by 35% in 2035 in the category of passenger vehicles in relation to the Reference Scenario or 10% compared to the total emissions in the transport sector in the Reference Scenario.

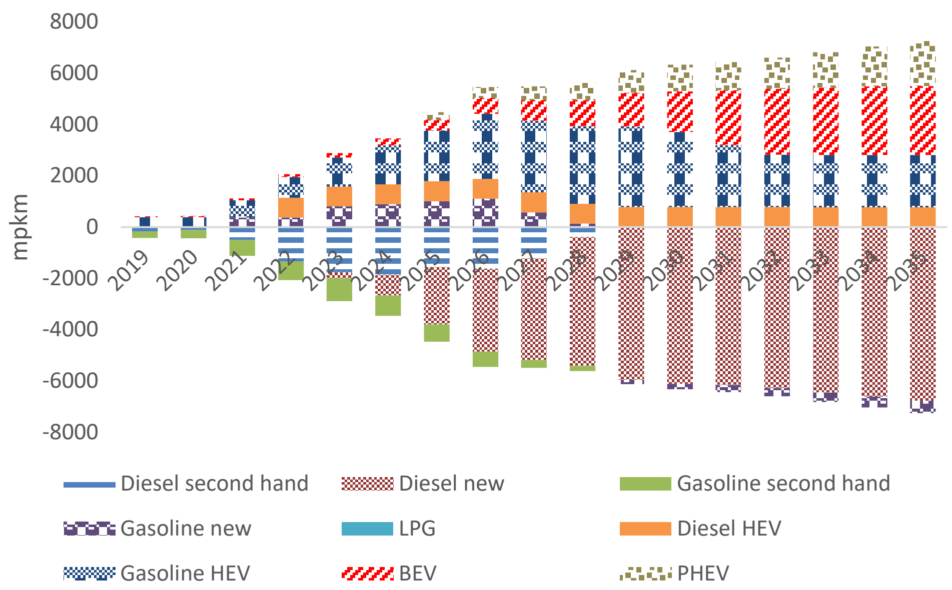


Figure 21. Difference in passenger km in scenario "Green & Smart" in relation to Reference Scenario

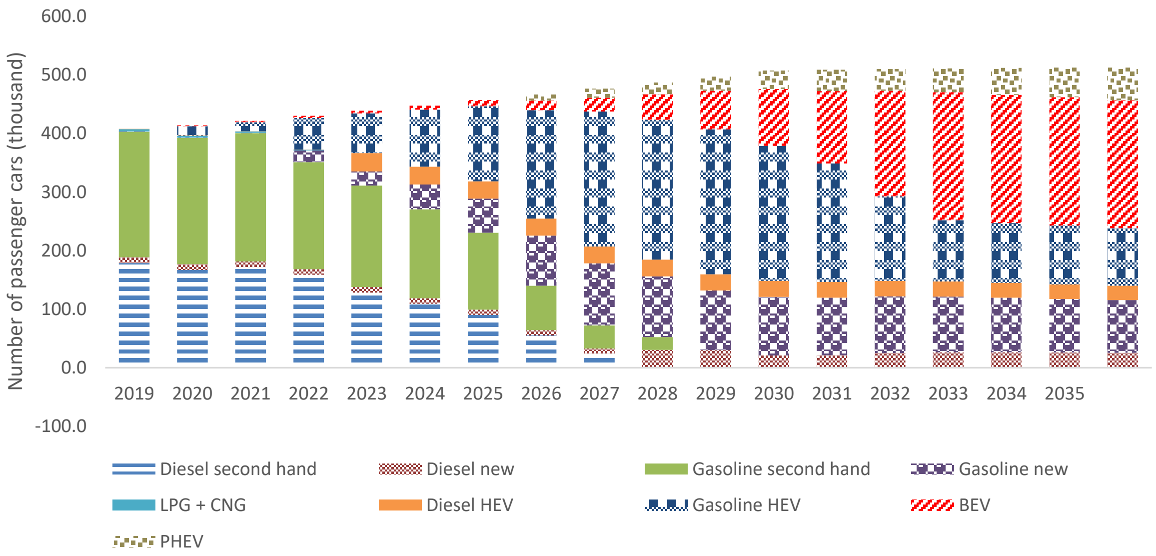


Figure 22. Number of passenger cars

An analysis has also been carried out if all measures are applied in the WAM scenario of the Second Biennial Update Report. In general, there is no difference in the category passenger vehicles within the transport sector if all measures are applied in the WAM scenario (Figure 23). With all measures applied, the reduction in the GHG emissions in this scenario is 35% compared to the Reference Scenario.

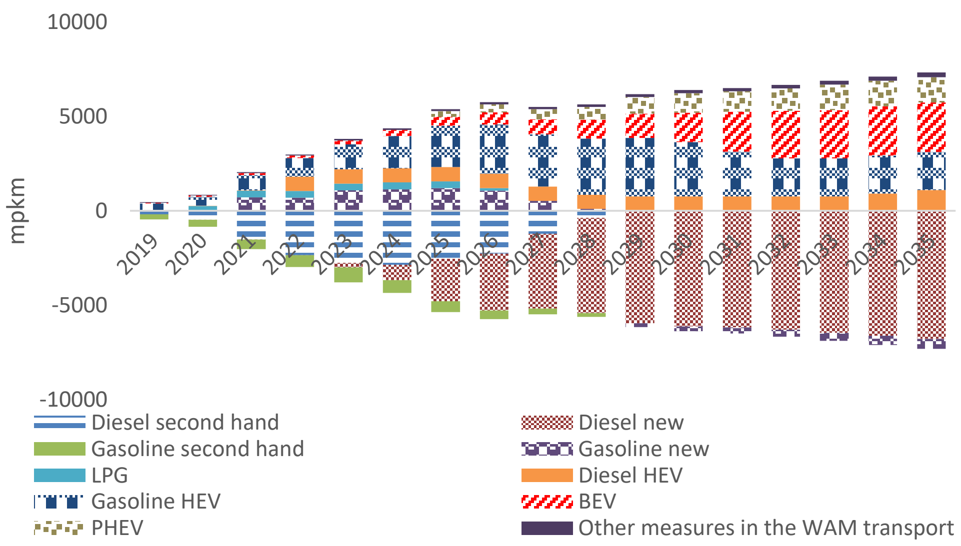


Figure 23. Difference in passenger km in the WAM scenario of the SBUR with all measures in transport compared to the Reference Scenario

It has to be said that direct and indirect subsidies for electric and hybrid vehicles should be continually controlled in order to prevent degradation of the market of passenger cars. In this regard, a sensitivity analysis was carried out, showing that VAT for hybrid vehicles can gradually increase as of 2020, reaching 15% by 2035, and in this way the market competitiveness of hybrid cars will be maintained.

Reducing GHG Emissions

Regarding the reduction of GHG emissions, each of the proposed measures has a different effect. Thus, the measure of equaling excise duties of fuels causes the least reduction of emissions, meaning that GHG emissions in 2035 are the same as in the Reference Scenario (Figure 24). The largest cuts are produced by the measure of direct subsidizing of electric cars along with the cancelling of excise duties and reducing the VAT to 5%. In this case, GHG emissions in 2035 are reduced by 17%. If all measures are applied in WEM_SBUR (Green&Smart) or WAM_SBUR, the reduction of emissions in 2035 amount to approximately 35% in comparison to the Reference Scenario. It is important to emphasize that the emission factor for electric vehicles is not based on the current European or Macedonian emission factor which takes the structure of the current energy system (mix of technologies and fuels used for electricity generation), but is based on the technologies and fuels mix that is provided from the WAM scenario in the SBUR.

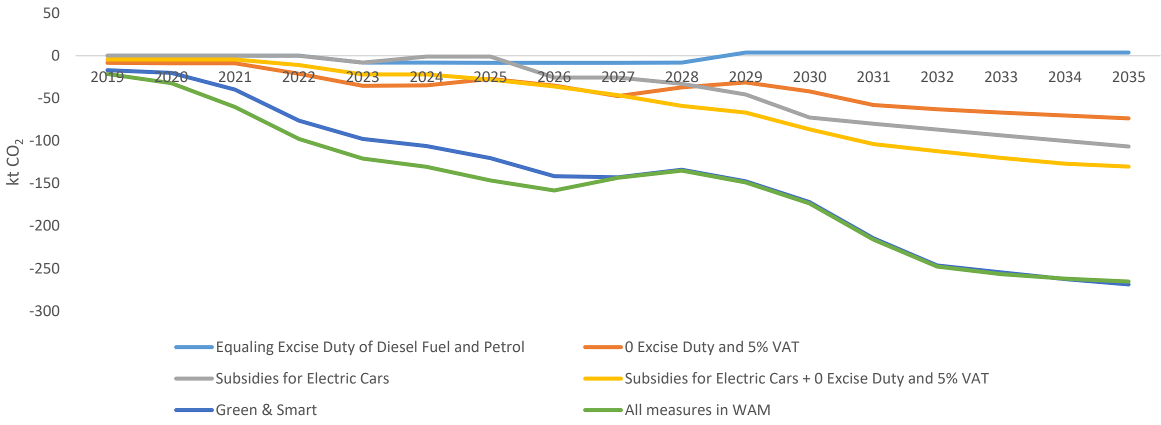


Figure 24. Reduction of GHG emissions in comparison to the Reference Scenario

Additional Benefits of Transport Electrification

Electric vehicles can contribute to direct reductions of CO_2 emissions in the transport sector, but also to increased penetration of renewable energy sources. Vehicles are parked 80-95 percent of the time, and if continually plugged in the grid, they can be used for smart charging, for e.g. when there is excess cheap power at the electricity market or to balance the system. Therefore, smart charging can satisfy the demand and enable greater penetration of renewable energy sources in the energy system accompanied by insignificant additional costs, because batteries and chargers are paid by the transport system.

For this purpose, the study includes an hourly analysis of scenarios developed for the needs of the Second Biennial Update Report (SBUR), supplemented by the proposed measures (in this study) in the passenger cars category of the transport system.

Reference Scenario (SBUR_WOM)

Results obtained from the EnergyPLAN model show that the share of renewable sources in electricity production is 12% in the Reference Scenario (SBUR_WOM). Furthermore, Figure 25 shows there are no problems in the system regarding critical electricity export, which points to the fact that the system is well-balanced.

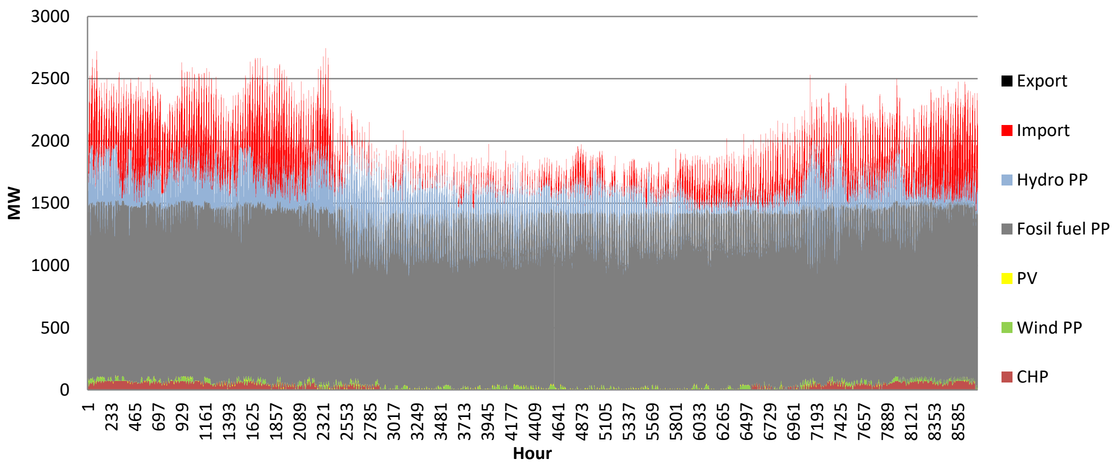


Figure 25. Production, export and import of electricity in 2035– SBUR_WOM scenario

Reference Scenario (SBUR_WOM) with measures in transport

If the Reference Scenario includes measures in transport, aimed at its electrification, Figure 26 shows there is again no critical electricity export. The share of renewable sources in electricity production is again 12.7%. As a result of applying the measures in the transport system using vehicles that spend less compared to conventional vehicles, CO_2 emissions are cut by 1% in relation to the Reference Scenario.

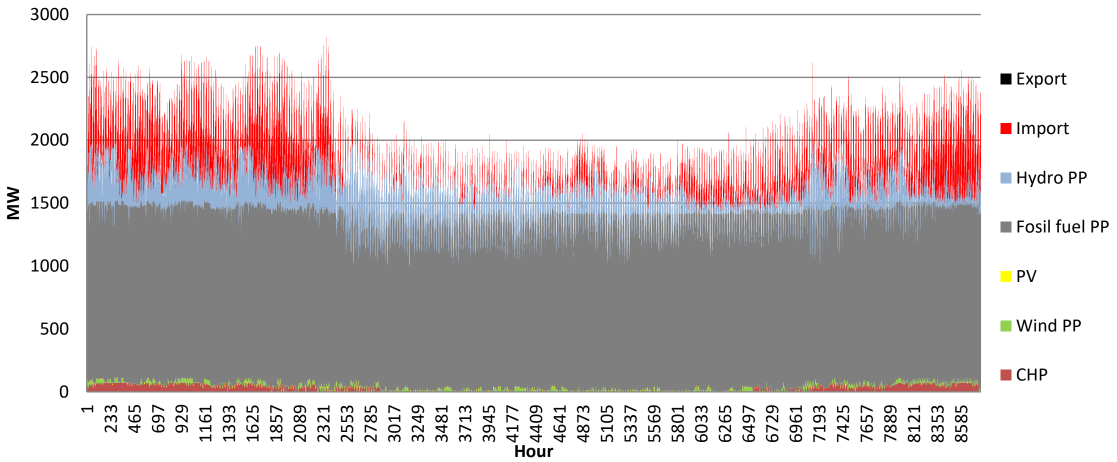


Figure 26. Production, import and export of electricity in 2035 – SBUR_WOM scenario with measures in transport

More ambitious mitigating scenario (SBUR_WAM)

The implementation of the measures from the more ambitious mitigation scenario (SBUR_WAM) contributes to radical increase in the share of renewable energy sources in electricity production. According to this scenario, the share of renewable energy sources in 2035 is projected to be 39.7% of the total production. Although there is a drastic cut in GHG emissions by 50% in comparison to the Reference Scenario, the hourly distribution of production, import and export of electricity (Figure 27) shows there are hours in which there is critical export, amounting to 10% of hours over the course of the year. This critical export reaches up to 300MW and the minimum amounts to 10MW. This problem contributes to misbalances in the system and its solution requires additional funds.

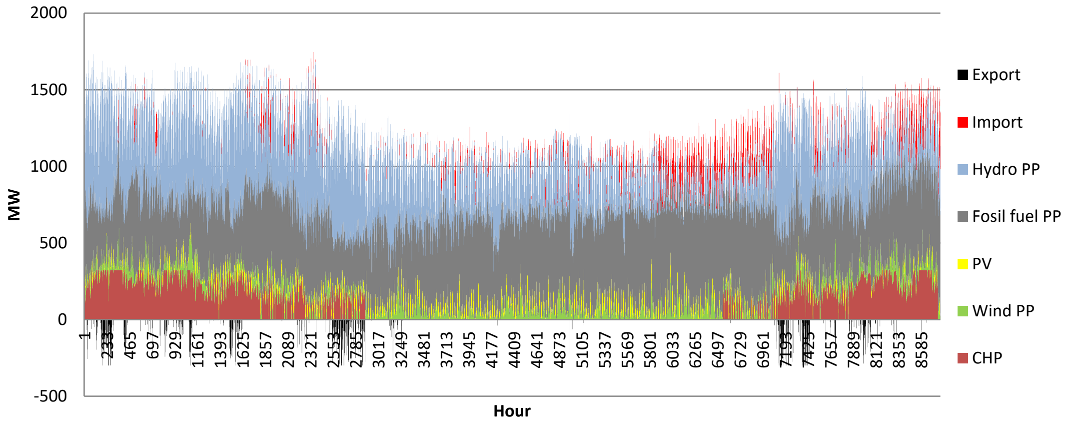


Figure 27. Production, import and export of electricity in 2035 – SBUR_WAM scenario

More ambitious mitigation scenario (SBUR_WAM) with measures in transport

One of the ways to solve the problem of critical export that emerges with the increased involvement of renewable energy sources is the inclusion of electric cars. Therefore, if the proposed measures in transport are applied, Figure 28 shows that the critical export would drop to zero. In this case, the share of renewable energy sources in total production increases by 1.4% and amounts to 41.1%. The hourly distribution of vehicle charging is presented in Figure 29, which shows that the potential of electric vehicles is used in the critical hours.

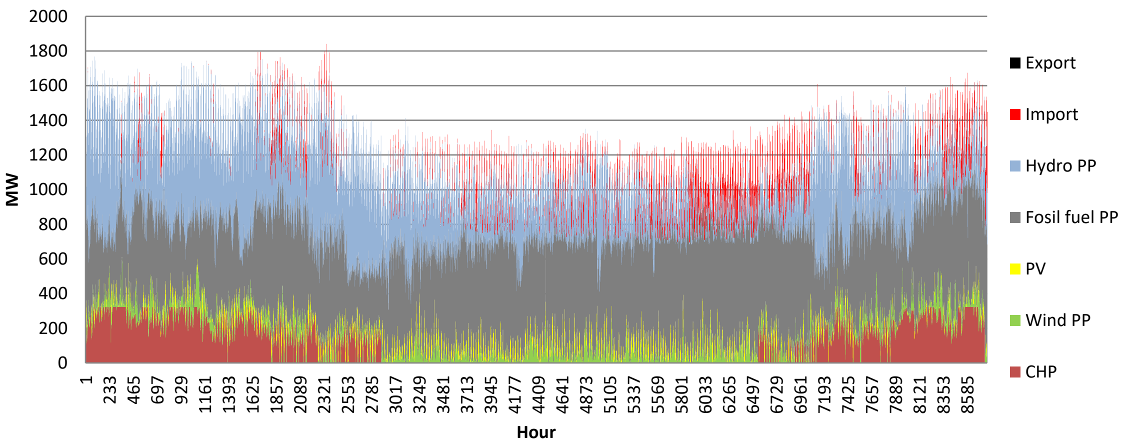


Figure 28. Production, import and export of electricity in 2035 – SBUR_WAM scenario with transport electrification

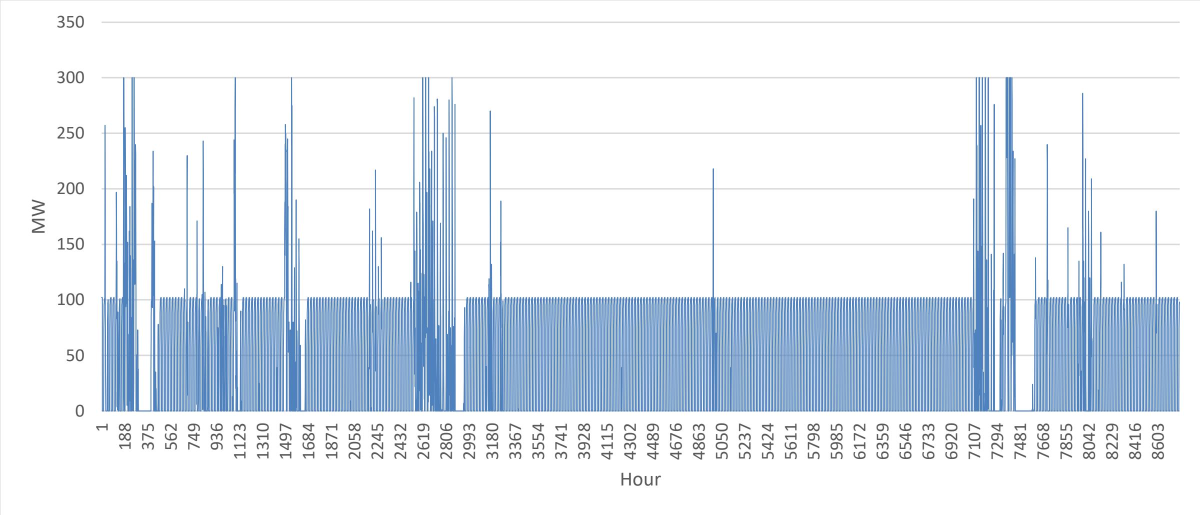


Figure 29. Charging of electric cars in 2035 - SBUR_WAM scenario with transport electrification

In order to investigate the maximum possibilities that electric cars provide for greater penetration of renewable energy sources, a scenario with twice as many wind (600MW) and solar (400MW) power plants was created in relation to the SBUR_WAM scenario. In this case, the share of renewable energy sources in the total production reaches approximately 50%. If the system does not include measures applied in the transport system, it can be seen (Figure 30) that there is critical export in 24% of hours. When applying the proposed measures in transport, the share of hours with critical export drops annually by 2% (Figure 31). In addition, a parallel optimization of hydro-plants' reservoirs and electric vehicles reduces the share of critical hours to less than 1% (Figure 32).

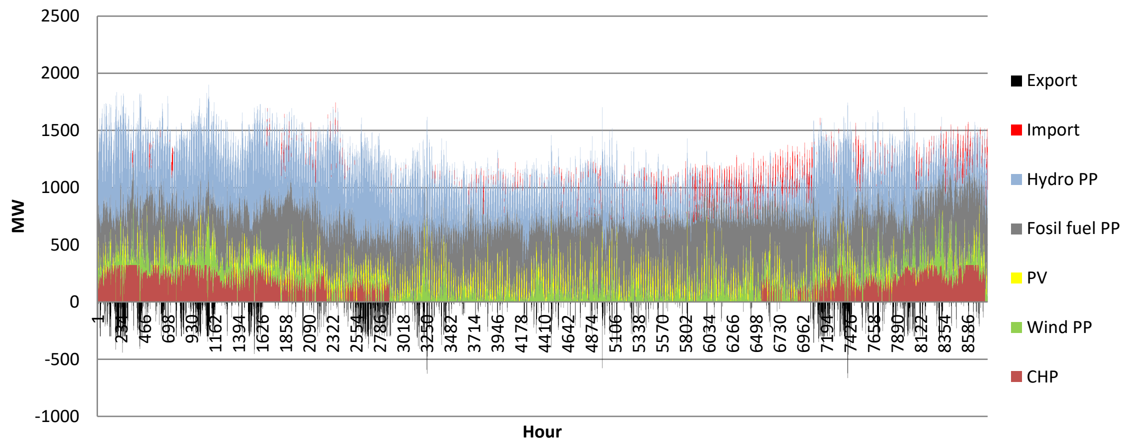


Figure 30. Production, import and export of electricity – twice as many wind and solar power plants in relation to SBUR_WAM scenario

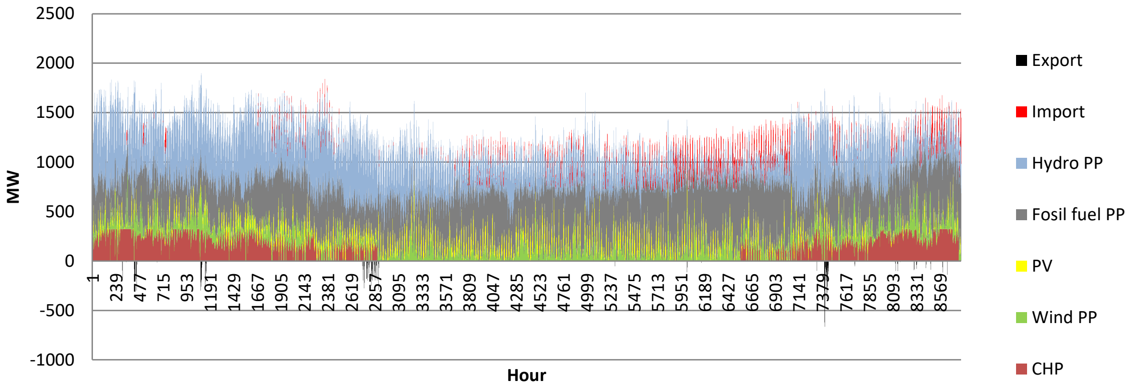


Figure 31. Production, import and export of electricity – twice as many wind and solar power plants in relation to SBUR_WAM scenario with transport electrification

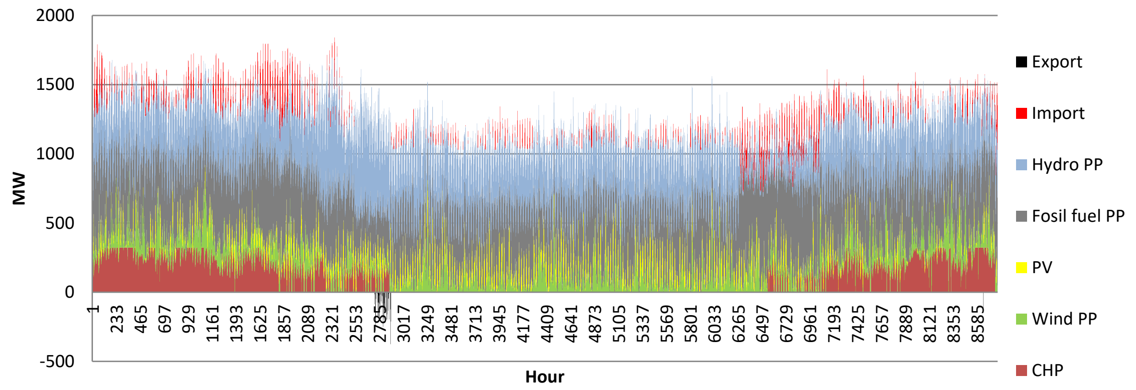


Figure 32. Production, import and export of electricity – twice as many wind and solar power plants in relation to SBUR_WAM scenario with transport electrification and hydro-plants optimization

Final Conclusions and Future Activities

From the analyses made, the following conclusions were drawn:

- It is necessary to change the methodologies for calculation of environmental taxes so that they will comply with European and global calculation methods;
- Excise duties of diesel fuel and petrol need to be gradually equaled;
- The exemption from paying excise duty for hybrid vehicles needs to continue, and it needs to be extended for electric vehicles as well;
- Reduction of VAT from 18% to 5% for hybrid and electric vehicles;
- Direct subsidizing of electric vehicles, and no additional direct subsidizing required for hybrid vehicles;
- Following the change of methodologies for calculation of environmental taxes, the collected funds should be allocated to special accounts and then used for direct subsidizing of electric vehicles;
- Implementation of a set of measures (comprehensive package) for faster renewal of the car stock and reducing GHG emissions by 35% in the sub-category passenger cars in comparison to the Reference Scenario, which is the main objective of the analyses within this study.

In addition to these measures and in order to make hybrid and electric vehicles more attractive for the consumers, the recommendations are the following:

- Reserved green parking in all public parking lots;
- Free parking or half-price parking (this is to be applied until 10% of vehicles are electric and hybrid);
- Chargers in all public parking lots;
- Free pay tolls (this is to be applied until 10% of vehicles are electric and hybrid);
- Allowed driving in bus lanes (this is to be applied until 10% of vehicles are electric and hybrid);
- Obligation to place fast chargers at all gas stations on motorways (at every 100km by 2020);
- Obligations of public institutions to purchase vehicles with low CO_2 emissions (up to 90 gCO_2/km by 2020 and 50 gCO_2/km by 2025). The quantified effects of this measure should also be analytically modeled and mitigation costs assessed.

In order to make electric cars more popular and enable additional de-carbonization of the transport sector, the following steps should be taken in the future:

- Analysis of local pollution from passenger cars and benefits from the introduction of hybrid and electric cars, especially in the cities of Skopje and Tetovo;
- Analysis of the correlation between driving hybrid and electric vehicles and the speed when driving in the city, possible contribution to reducing the average driving speed on

the city streets, thus reducing the exhaust gasses emissions and consumption, and ensuring better traffic safety and fewer number of traffic accidents.

- Detailed analysis of policies and measures in Europe and in global terms regarding the increase of efficiency and electrification of light transport vehicles. Adaptation and assessment of the effects of such measures is required in the transport system in Macedonia;
- Analysis of the optimal development of infrastructure for electric vehicle chargers, taking into account traffic characteristics and the energy grid;
- Assessment of the effect of equaling prices of petrol and diesel fuel on the entire transport sector in Macedonia;
- Detailed analysis of public transport electrification.

Annex I – Taxes for Motor Vehicles in the EU

Table 8. Taxes for vehicles (VAT and based on CO_2 emissions) valid in EU

	VAT	Type of tax One-off	Annual
AUSTRIA	20%	Fuel consumption tax (Normverbrauchsabgabe or NoVA) is charged at first registration of the passenger vehicle. It is calculated in the following way: (CO_2 emissions in g/km minus 90 then divided by 5) minus NoVA deduction, plus NoVA,"malus". As of 1 January 2016, the tax for official vehicles is based on CO_2 emissions.	
BELGIUM	21% 6% [m][14]	Tax for official vehicles is based on CO_2 emissions. Deductions complying with corporate tax on expenses related to the use of official vehicles (50% to 120%) are linked to CO_2 emissions. The Wallonia region operates with the "malus" system, where vehicles releasing 146 g/km or more pay fines (maximum of 2,500 euros for cars that release 256 g/km or more). The first registration tax in Flanders is based on CO_2 emissions and standards for exhaust gases, fuel and age of vehicle.	As of 1 January 2016, a new "green" annual tax paid at annual registration based on CO_2 emissions has been introduced in the Flemish region.
BULGARIA	20%	None	
CROATIA	25%	First registration tax is based on CO_2 emissions and type of fuel	
CYPRUS	19%	First registration tax is based on CO_2 emissions.	Annual registration tax is based on CO_2 emissions.
CZECH REPUBLIC	21%	None	
DENMARK	25%		Annual registration tax is based on fuel consumption: Cars using petrol: semi-annual rates range from 310 DKK (Danish Crown) for cars driving at least 20 km per liter of fuel,

[14][m] = taxation on the margin

			up to 10.830 DKK for cars driving less than 4,5 km per liter of fuel. Cars using diesel: semi-annual rates range from 130 DKK for cars driving at least 32,1 km per liter of fuel, up to 16,100 DKK for cars driving less than 5,1 km per liter of fuel. Cars using LPG or biogas: rates are the same as for cars using diesel fuel. The equivalent consumption of diesel fuel is calculated by dividing the value of CoC for CO_2 /km by a fixed factor of 26,5.
ESTONIA	20%	None	
FINLAND	24%	First registration tax is based on CO_2 emissions. Rates range from 3,8 up to 50%. The tax will reduce in four steps between 2016 and 2019 for cars having CO_2 emissions of 141 g/km or less.	Annual registration tax is based on CO_2 emissions for cars registered as of 1 January 2001 (total mass up to 2,500 kg) or as of 1 January 2002 (total mass exceeding 2,500 kg), and for vans registered as of 1 January 2008. Values range from 106,21 euros up to 654,44 euros. Excise duty for fuels in road traffic depend on the energy content (calorific values) and CO_2 emissions of the fuel.
FRANCE	20%	According to bonus-malus system, premium for purchase of new electric vehicle is awarded. For a vehicle (car or light transport vehicle - LTV) emitting between 21 and 60 g CO_2/km, the bonus amounts to 1,000 euros. For a vehicle (car or LTV) emitting 20 g CO_2/km or less, the bonus amounts to 6,300 euros. An additional bonus of 200 euros is approved when an older vehicle (at least 15 years) is disposed. As of March 2015, there is an additional scheme for disposal of diesel vehicles registered in 2006 or earlier (maximum bonus is 4,000 euros for emissions of 20 g CO_2/km or less). "Malus" is paid for purchase of a car which CO_2 emissions exceed 127 g/km. The maximum tax amounts to 10,000 euros (over 190 g CO_2/km). Cars emitting more than 190 g/km pay an annual tax of 160 euros. Tax on official vehicles is based on CO_2 emissions. Tax rates range from 2 euros for each gram emitted between 50 g/km and 100 g/km up to 27 euros for each gram emitted over 250 g/km.	
GERMANY	19%		Annual registration tax for cars as of 1 July 2009 is based on CO_2 emissions. It is comprised of base tax and CO_2 tax. The base tax is 2 euros for 100 cm^3 (for cars using petrol) and 9,50 euros for 100 cm^3 (for diesel cars). The CO_2 tax is linear at 2 euros for g/km emitted over 95 g/km. Cars with CO_2

			emissions below 95 g/km are exempted from the CO_2 tax component.
GREECE	24%	First registration tax is based on CO_2 emissions. The coefficient of CO_2 emissions ranges from 0,95 – for vehicles emitting up to 100 g/km – to 2,00 for vehicles emitting more than 250 g/km.	Annual registration tax for cars registered as of 31 October 2010 is based on CO_2 emissions. Rates range from 0,90 euros per gram of emitted CO_2 (91 – 100 g/km) to 3,72 euros per gram (251 g/km or more). Cars having emissions up to 90 g/km are exempted.
HUNGARY	27%	None	
IRELAND	23%	First registration tax is based on CO_2 emissions. Rates range from 14% for cars with CO_2 emissions of 80 g/km up to 36% for cars with CO_2 emissions of 226 g/km or more. VAT is deducted for cars registered as of 1 January 2009 with CO_2 emissions less than 156 g/km and which are primarily used (at least 60%) for business purposes.	Annual registration tax for cars registered as of 1 July 2008 is based on CO_2 emissions. Values range from 120 euros (0 g/km) up to 2,350 euros (226 g/km or more).
ITALY	22% 4% [m][15]	None	
LATVIA	21%	First registration tax is based on CO_2 emissions. Prices range from 0,43 euros per g/km for cars emitting 120 g/km or less, to 7,11 euros per g/km for cars emitting more than 350 g/km.	
LITHUANIA	21%	None	
LUXEMBOURG	17%		Annual registration tax for cars registered as of 1 January 2001 is based on CO_2 emissions. Tax rates are calculated by multiplying CO_2 emissions in g/km by 0,9 for diesel cars and 0,6 for cars using other fuels, and by the exponential factor (0,5 below 90 g/km and increased by 0,1 for every additional 10 g CO_2/km).
MALTA	18%	First registration tax is calculated on the basis of CO_2 emissions, price and length of vehicle.	Annual registration tax is based on CO_2 emissions and age of the vehicle. Over the first five years, the tax depends only on CO_2 emissions and varies from 100 euros for a car emitting 100 g/km up to 180 euros for a car emitting between 150 g/km and 180 g/km.
NETHERLANDS	21%	First registration tax (Belasting Personenauto Motorrijwielen or BPM) is calculated on the basis of CO_2 emissions. Values range from 2 euros (between 1 and 76 g CO_2/km) up to 475 euros (for 169 g CO_2/km and more). Cars with zero CO_2 emissions are exempted. As of 1 January 2017, a special BPM rate is applied for all new PHEVs. In addition, a 353 euros tax	

[15][m] = taxation on the margin

		is charged on all cars emitting 1 g/km or more, and diesel cars emitting more than 65 g/km (from 86,69 euros for each gram of CO_2 over 65 g/km). Passenger cars with zero CO_2 emissions are exempted from the motor vehicle tax up to 2020. Tax on official vehicles is based on CO_2 emissions (if private use exceeds 500 km per year). Rates range from 4% (for cars using petrol and diesel emitting 0 g CO_2/km) up to 22% (for all other cars).	
POLAND	23%	None	
PORTUGAL	23%	First registration tax is based on the capacity (volume) of engine and CO_2 emissions. Prices are calculated in the following way: • Lowest prices: cars using petrol emitting up to 99 g CO_2/km pay [(4,12 x CO_2) – 381,10] EUR; cars using diesel fuel emitting up to 79 g CO_2/km pay [(5,15 x CO_2) – 391,40] EUR • Highest rates: cars using petrol emitting more than 195 g CO_2/km pay [(183,34 x CO_2) – 29.767,00] EUR; cars using diesel fuel emitting more than 160 g pay [(239,30 x CO_2) – 29.818,50] EUR	Annual registration tax for cars registered as of 1 July 2007 is based on CO_2 emissions.
ROMANIA	19%	None	
SLOVAKIA	20%	None	
SLOVENIA	22%	First registration tax is based on the price and CO_2 emissions. Rates range from 0,5% (petrol) to 1% (diesel) for cars emitting up to 110 g CO_2/km and from 28% (petrol) to 31% (diesel) for cars emitting more than 250 g CO_2/km.	
SPAIN	21%	Special tax (IEDMT, *Impuesto Especial sobre Determinados Medios de Transporte*) is applied at first registration and is based on CO_2 emissions. Rates range from 4,75% (121 – 159 g CO_2/km) up to 14,75% (200 g CO_2/km and more).	
SWEDEN	25%	Premium (Supermiljöbilspremie) is awarded for purchase of new electric or hybrid vehicle: • 20,000 SEK (Swedish Crown) for cars having CO_2 emissions from 1 up to 50 g/km (plug-in hybrid vehicles). • 40,000 SEK for cars with zero CO_2 emissions (electric cars).	Annual registration tax for cars meeting at least Euro 4 standards is based on CO_2 emissions. The tax is comprised of a base rate of 360 SEK (Swedish Crown) plus 22 SEK for each gram of emitted CO_2 over 111 g/km. This amount is multiplied by 2,37 for diesel cars. Diesel engines registered for the first time in 2008 or later pay additional 250 SEK, while those registered earlier pay additional 500 SEK. For vehicles using alternative fuel, the tax amounts to 11 SEK for each gram of emitted CO_2 over 111 g/km. Five-year exemption from annual registration tax is applied for green cars (definition is partly based on CO_2 emissions).

GREAT BRITAIN	20%	First registration tax is applied as of 1 April 2010. Rates range from GBP 0 (up to 100 g CO_2/km) up to GBP 1,120 (more than 255 g CO_2/km). Cars using alternative fuels get a discount of GBP 10 for paid rates. The obligation for tax on individual official vehicles is based on CO_2 emissions.	Annual registration tax for cars registered as of March 2001 is based on CO_2 emissions. Prices range from GBP 0 (up to 100 g CO_2/km) up to GBP 515 (more than 255 g CO_2/km).

Source: http://www.acea.be/uploads/publications/CO2_tax_overview_2017.pdf

Annex II – Methodology

MARKAL model

In order to project the required energy in the period up to 2035, the software package MARKAL (MARKet ALlocation) was used. MARKAL is a complex model for planning the development of the entire energy sector at local, national and/or regional level. Various parameters, such as prices of energy and energy resources, prices of power plants and their traits, characteristics of facilities etc, are the input data based on which the program selects an optimal technological mix to meet the energy demand at a minimal price.

In order to meet electricity needs, the MARKAL model selects those technologies that have the lowest price of electricity production, including investment costs into certain energy facilities, fixed and variable maintenance costs, as well as costs for fuel spent by certain power plant, or if imported electricity is cheaper, then such import is carried out. In the framework of the optimization process, MARKAL creates a balance of power and produced electricity.

The model is divided in two parts – energy supply and demand. There are two types of technologies on both the supply and demand sides: existing and new. Existing technologies are those that are used in the base year, in this case 2012. These technologies have a certain lifespan after which they are replaced by new technologies.

EnergyPLAN model

The EnergyPLAN[16] model is an analytical tool designed for analyzing the energy systems on regional and national level. This model is an entry-exit model, using data on the capacities and the efficiency of capacities for energy conversion in the system, and availability of fuels and renewable energy sources. It provides hourly calculations on the meeting of electricity and heating needs in the entire system during given limitations and strategies for system regulation. This type of calculation is of essential significance in assessing the introduction of vehicles-to-grid (V2G) in the system that involves a large portion of renewable energy sources. Figure 33 illustrates the model's operations, encompassing interactions among electricity, heating and fuels used in transport, although the focus is put on the electricity system. This makes EnergyPLAN suitable for analysis of combined energy system.

[16] H. Lund, Tech. Rep., Aalborg Univ. Denmark (2014)

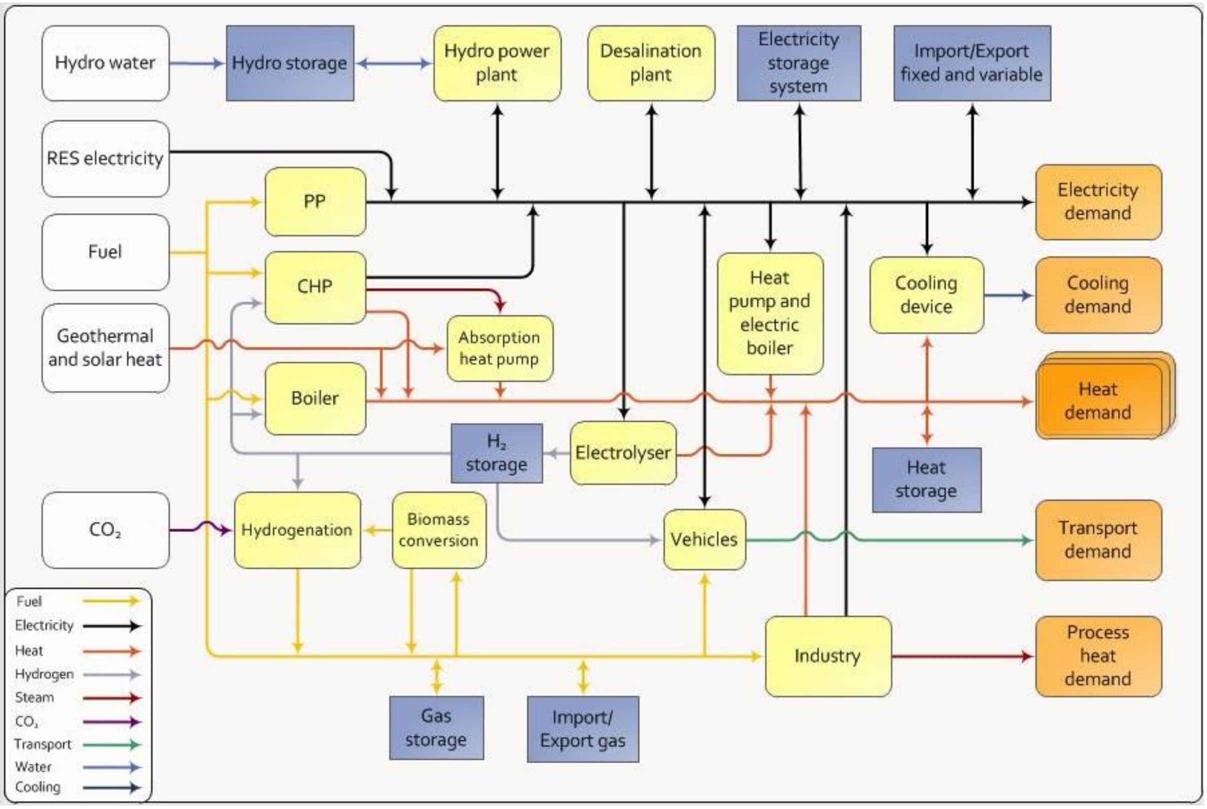


Figure 33. EnergyPLAN model for analyzing energy systems

The model uses historic data of electricity production rates and energy conversion systems for the energy system that is subject of analysis, and calculates how fluctuating energy needs are to be met under given specific limitations. The model also uses information on the energy accumulation capacities, planned investments and regulating strategies. By using all data, the model calculates: import costs and export revenues, costs for critical energy surplus, fuel consumption, fixed and variable operational costs, systemic-economic costs, CO_2 emissions and share of renewable sources. In order to define the connection of V2G with the power grid, we provide the following entry data: (1) energy demand of electric vehicles in TWh/year, (2) portion of the PEV linked to the grid and available during peak load, (3) maximum grid capacity to link electric vehicles in MW, (4) efficiency of two-way charger/inverter between the PEV and the power grid, and (5) capacity of battery storage in GWh.