THERMAL VERSUS ELECTRIC MOTORS AND THE ENVIRONMENT

Costel Ioan CIOBAN

Faculty of Mechanical Engineering, Automotive and Robotics
costel.cioban@usm.ro.

Abstract: *This article presents information on the environmental effects of thermal engines and electric motors and some of the proposed solutions to mitigate the problems caused by the operation of thermal engines. In the introduction some of the economic and environmental benefits of electric motors are presented. This information has been taken from articles and studies by various experts in the field. According to them, emissions of various gases into the environment from vehicles with internal combustion engines can be reduced or even eliminated by replacing them with electric motors. The research carried out has highlighted the types of electric cars, their characteristics and the fact that these electric cars emit CO2 during their use and during their production. In order to reduce and even eliminate these gas emissions, we pointed out that in May the European Parliament's Committee on the Environment approved the target of zero emissions by 2035. In the same context, I pointed out that the European Parliament adopted the European Climate Act. Also, the information on the websites of the European Union institutions shows the evolution of energy consumption and CO2 emissions worldwide - these data were obtained as a result of the efforts of various researchers/specialists in the field. .*

Keywords: *CO2 emissions, electric batteries, thermal engines, environment, fuel*

1. Introduction

In this paper we show that thermal engines compared to electric engines operate on a thermodynamic cycle using a fuel (diesel, gasoline, kerosene, natural gas, coal, etc.) that removes sulphur compounds (SO2, H2S), nitrogen oxides and lead compounds into the atmosphere. In this context, the operation of heat engines has the following effects on the environment [23]:

- ✓ a decrease in the amount of O2 in nature;
- ✓ an increase in CO2 (the main contributor to climate change);
- ✓ damage to vegetation and animals;
- ✓ destruction of the ozone layer;
- ✓ release of huge amounts of dust;
- ✓ warming of the atmosphere and the greenhouse effect leading to (Figure 1)
- ✓ the occurrence of acid rain (as a result of the reaction between some of the gases released and water vapour) leading to (Figure 2)

✓

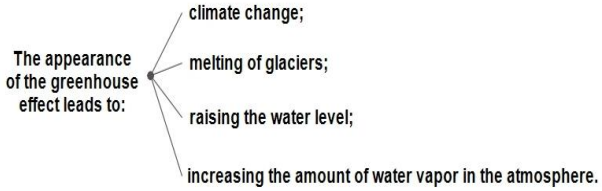

Figure 1 - *Greenhouse effect results*

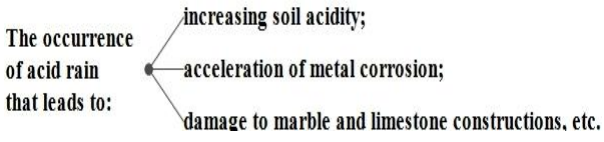

Figure 2 - *Effects of acid rain*

These results are becoming more and more striking, as the amounts of dust and gases emitted by thermal engines are increasing considerably. In this context, people/researchers/policy makers are trying to find ways to address the adverse effects of the operation of thermal engines. The first

solutions to mitigate the problems caused by the operation of thermal engines are (Figure 3):

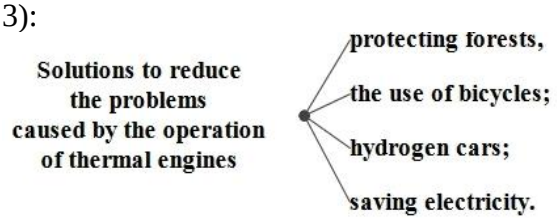

Figure 3 - *Solutions to mitigate problems caused by the operation of heat engine*

We can also list some technical tips for the population to follow (figure 4):

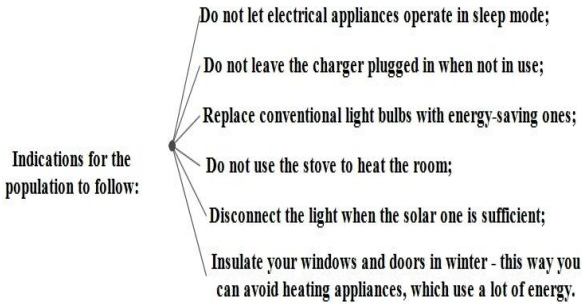

Figure 4 - *Technical advice for the population*

The information presented must be linked to requirements to ensure the most complete combustion of fuels, increase engine efficiency and research into environmentally pure fuels. This is necessary because the transport sector, and in particular road transport, is a source of pollution affecting the health of the population [2, 8].

With regard to electric engines, we can show that they have important advantages from both an economic and environmental point of view. Thus, electric motors have a minimum level of toxic gas emissions - which promise cleaner urban air [5], low maintenance and operating costs and a high level of comfort [19].

The advantages of electric motors are as follows:

- ✓ the minimal toxic gas emissions produced when making electricity - and the very low impact on the environment (the pollution charge is low compared to cars with heat engines);
- ✓ low running costs;
- ✓ maintenance of electric motors is much less costly because they do not use substances that could damage the engine over time, and the level of wear and tear is much lower with an electric motor;
- ✓ electric motors offer a certain comfort due to their quiet operation.

In addition to this information, we show that the use of electric motors on an industrial scale has led to the creation of new jobs in their production, repair, development and research.

We also point out that they are indispensable in construction (tall buildings cannot be erected without the intervention of cranes powered by electric motors), in households (household robots), etc.

Disadvantages of electric cars include: the initial cost of an electric car is higher than a conventional diesel or petrol car, but in the long term the cost of powering an electric vehicle is expected to be much cheaper; they take significantly longer to charge and will consume extra energy to heat the interior and windscreens to prevent condensation in cold weather, leading to an estimated reduction in range of up to 28% in some situations [7].

Note that electric motors are powered by electricity and if electricity is not produced from sustainable sources, then they will pollute the environment. Also, a number of materials used in electric motors are mined and mining has a direct impact on the environment.

At the same time, taking electric motors out of service requires them to be handed over to a recycling centre, which must remove the hazardous components from the motor before it is discarded.

In this respect, the invention or commissioning of an electric motor by Michael Faraday in 1832 (by putting into practice two key principles, electromagnetic rotation (in 1821) and electromagnetic induction (in 1831), made an important contribution to the development of the technology. Faraday took the ideas and theories about electricity that existed at the time and turned them into something

concrete, practical and useful (converting electric current into mechanical energy).

The electric motor played a key role in the 'second industrial revolution' that lasted from 1870 to 1914. Electric motors have become part of modern society and are used in many areas of activity.

In conclusion we show that strategies are needed based on stabilising (greenhouse) gases in the atmosphere and improving fuel economy; supplying production sites with 100% renewable energy from local sources and implementing a totally carbon-free production system by 2050 [6]; constant improvements in technologies; production of hybrid and full-electric vehicles, vehicles with LPG (liquefied petroleum gas) fuelling systems; reduction of CO2 emissions through the driving style adopted.

We note that the use of electric cars has brought a lot of controversy into the public arena. World-renowned publications point out that the use of electric cars does not solve the problems of traffic congestion; building more roads would lead to less green space and living areas in cities [27]; it does not solve the problem of parking; the greater need for electricity could transfer pollution from cars to power plants; a greater need for electricity will lead to an increase in oil consumption (Economic Times [13, 24]) by 2030.

In this context, Lauri Myllyvirta, (senior analyst at Greenpeace's air pollution analysis unit) said: "Electrification is a necessary part of deep decarbonisation because it is relatively easy to decarbonise the power sector" adding that "electrification only helps if the power sector moves rapidly towards zero emissions."

2. Research methodology: aim and objectives

The present work is based on a thematically documented analysis, primarily through specialist literature - books, specialist treatises, articles, studies, etc., the national and international legislative system in the field, reports from national/European institutions, as well as information material from economic agents and various online resources. These information resources have familiarised us with the theories and the beneficial effects of electric motors on the environment.

This information was processed using certain methods: investigation and analysis, observation, comparative analysis, synthesis. The use of these methods helped us to highlight the advantages of using electric motor cars compared to using thermal engine cars.

The aim of this paper is to paint a picture of the need for the introduction of an increasing percentage of electrically powered cars. Achieving this goal requires specific objectives:

- ✓ to identify the characteristics of electric motor cars and their environmental effects;
- ✓ Comparative analysis of CO2 emissions from thermal and electric cars;
- ✓ to investigate the socio-economic advantages of thermal engine cars.

The rationale for this work is based on the need to reduce and eliminate emissions into the environment.

3 Electric car engines - Characteristics of electric motors [22]

An important moment in the history of electric cars is the production of the first electric carriage (in 1832) by Scottish inventor Robert Anderson. The second important moment in the development of electric cars is identified in 1859 when the French physicist Gaston Plane invented the rechargeable lead-acid battery. About three decades later (in 1884) the first electric car was made in Europe by the British Thomas Parker, and in 1860 the Scotsman William Morrison presented a similar vehicle in America [12]. It should be noted that at the beginning of the 20th century, one third of the cars running in the USA were electric [4, 25]. However, production of cars with combustion engines grew rapidly and took over the entire

market. The argument in favour of this type of engine (internal combustion) was: lower production price, lower fuel prices, higher running speed, better range and less time for refuelling, fast production. The electric cars were very dense and were put aside, and attempts were made to revive them in the 1970s but without success. After about four decades General Motors was producing over 1000 units (assembly was stopped in 1999). The 21st century has brought clear signals that the near future is electric cars (Tesla Motors debut in 2000, Nissan Leaf in 2010) as incumbent manufacturers have increasingly invested in electric technologies. Today's electric cars are performing differently and have characteristics increasingly similar to those of internal combustion cars [26]. Electric cars are known by the acronym EV (Electric Vehicle) and are classified into Battery Electric Vehicles (BEV) (Image.1) and Fuel Cell Electric Vehicles (FCEV). (Image.2).

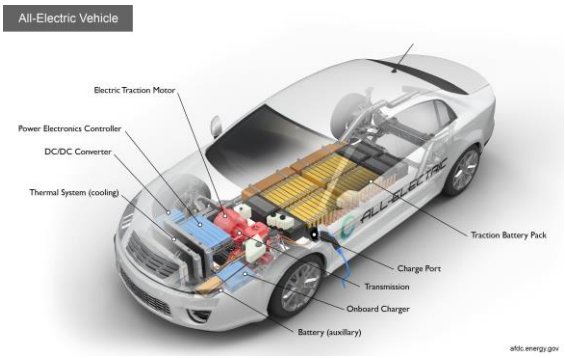

Image.1 - *Battery Electric Vehicle, BEV*
Source: www.afdc.energy.gov/vehicles/how-do-all-electric-cars-work

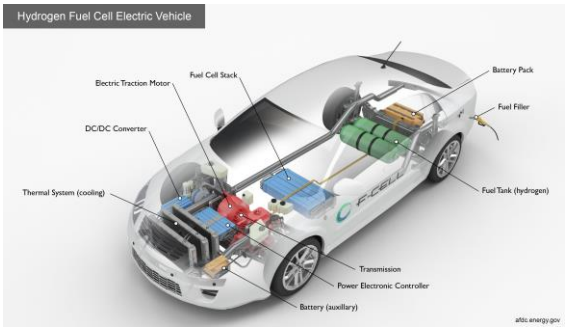

Image.2 - *Fuel Cell Electric Vehicle, FCEV*

Source: www.afdc.energy.gov/vehicles/how-do-fuel-cell-electric-cars-work

So there are electric cars (BEVs) with two or three electric motors that store the energy needed to run the motor(s) in a battery pack.

EV batteries can be exploited as an additional grid storage reserve, where surplus renewable energy can be stored and balance the variation in electricity demand [1, 11]. These reserves could also be used in emergency situations or during unplanned power outages [1, 11].

Features of electric machines:

- ✓ specific electric sockets or charging stations are used for recharging batteries (the most powerful public stations have an output of 350 kW): alternating current (AC) and direct current (DC) with higher power and shorter waiting times;
- ✓ capacity / value expressed in kWh: high capacity leads to long range (the distance travelled by a vehicle will be long);
- ✓ increasing battery capacity means increasing battery size, but new technologies improve battery capacity without increasing battery size and mass;
- ✓ electric motors operate at high revs; they are efficient over a wider range of revs and have almost instantaneous torque availability; they use a fixed-ratio mechanical gearbox or, as can be found in the literature, a single-speed transmission - one German manufacturer's model currently uses a two-speed transmission on the rear axle to improve acceleration and efficiency at high speeds;
- ✓ the inverter has a dual role: when the engine starts the wheels, the inverter converts the battery's direct current (DC) into alternating current (AC) and sends it to the engine. When the electric motor becomes the generator (during deceleration/braking periods), the inverter converts the AC into DC and will charge the battery;
- ✓ power control and distribution unit: regulates the transfer of electricity

between the battery, the inverter and the charging system from an external source;

- ✓ temperature management system: batteries operate efficiently at certain temperatures, so there is a special cooling system to keep the batteries within the optimum temperature range at all times;
- ✓ DC-DC converter (replaces the alternator): takes energy from the high-voltage batteries and converts it into 12V power - electric cars use a 12V electrical system to power auxiliary systems (lighting system, multimedia system, seat heating);
- ✓ on-board charger: converts the AC current received from the external grid (socket/charging station) into the DC current needed to charge the high-voltage batteries;
- ✓ the electric machine operates when the energy from the batteries is transformed by the inverter and regulated by the control unit, and then goes to the electric motor. Its rotation engages the single-speed transmission, which in turn sets the wheels in motion;

In hydrogen fuel cell electric cars (FCEVs), the electrical energy needed to run the engine is obtained through a complex electrochemical reaction that takes place in a special 'cell'. The vehicles (FCEVs) run on high-pressure liquid hydrogen and the resulting electricity can be used directly by the electric motor or indirectly through intermediate storage in a battery pack. Production for this type of vehicle is low due to poorly developed infrastructure (special liquid hydrogen refuelling stations).

3.1 CO2 emissions of thermal and electric motor vehicles

The European Environment Agency (EEA) report shows that at EU level transport was the source of about a quarter of CO2 emissions in 2019. It should be noted that 71.7% of CO2 emissions came from road transport. Over the last three decades, greenhouse gas emissions in the transport sector increased by 33.5% between 1990 and 2019 (Figure 5):

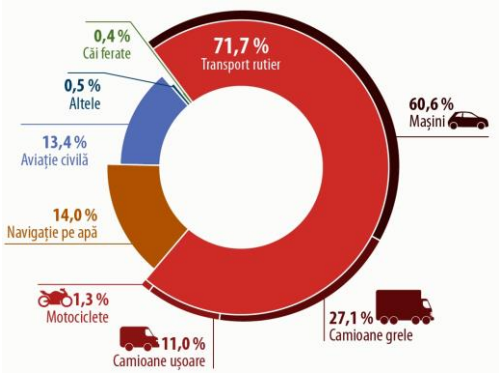

Figure 5 - *Greenhouse gas emissions by transport model for 2019*
Source: European Environment Agency (EEA) - 2022-11-14 [10, 15]

The information provided by the EEA shows that road transport accounts for about one fifth of EU greenhouse gas emissions. Statistics show that private cars pollute the most, emitting 60.6% of total CO2 emissions from European road transport [3]. We show that in the European Union, almost 72% of total CO2 emissions come from the transport sector [9].

These results call for strategies to achieve the target of reducing transport emissions to just 22% by 2050. The EEA also shows that in 2018 in Europe, each private car carries an average of 1.6 people and that switching to car sharing, public transport, cycling and walking can reduce emissions.

Reducing CO2 emissions from cars can be done both by making them more efficient and by switching fuel. In 2019, the majority of road transport in Europe used diesel (66.7%), followed by petrol (24.55%).

An advantage in reducing emissions is the marketing and use of electric cars. Sales of electric vehicles (fully electric or plug-in hybrids) tripled between 2017-2020, with electric cars accounting for 11% of all new car registrations in 2020 (Figure 6). Studies show that global demand for electric batteries will increase 14-fold by 2030, and the EU could produce 17% of this demand. It is noted that the Environmental Commission wants guarantees that new batteries will contain a

minimum percentage of cobalt, lead, lithium and nickel and will be recycled. The percentage of portable batteries sold in the EU for recycling was 51% in 2019 (Figure 7).

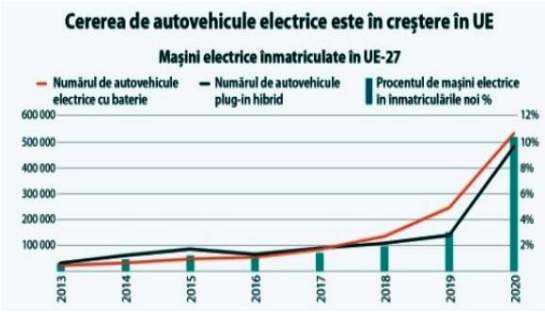

Figure 6 *Electric cars registered in UE-27*
Source: Parlamentul European, 2021; Comisia Europeană, 2020; Serviciul de cercetare al Parlamentului European, 2021; Forumul Economic Mondial, 2019; Agenția de Mediu, 2021
www.europarl.europa.eu/news/ro/headlines/priorities/economia-circulara/20220228STO24218/noi-reguli-ue-pentru-baterii-mai-durabile-si-mai-etice

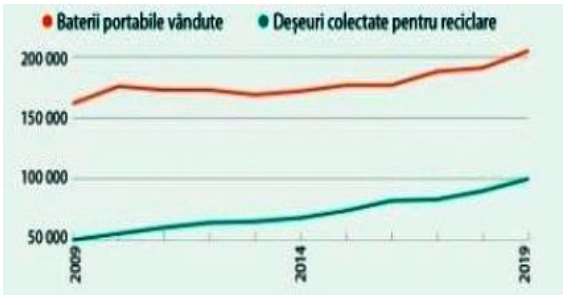

Figure *7 Battery recycling in the EU; Sales and collection of portable batteries and accumulators in UE27 (tone)**
** Date estimate de Eurostat din 2009 până în 2014 și 2019*
Source: Eurostat (online data code: ENV_WASPB) 2021www.europarl.europa.eu/news/ro/headlines/priorities/economia-circulara/20220228STO24218/noi-reguli-ue-pentru-baterii-mai-durabile-si-mai-etice

3.2 Electric vans accounted for 2.3% of the market for newly registered vans in 2020.

To know how much CO2 a car produces, we need to consider not only CO2 emissions during use, but also emissions from production and disposal.

The information so far shows that the production of electric cars is less environmentally friendly than the production of an internal combustion car. At the same time, emissions from electric vehicles vary depending on how the electricity is produced. However, Europe's electricity production is "getting cleaner", making electric cars less harmful to the environment. Emissions from electric cars will also be lower thanks to the EU's plans [17] to produce more sustainable batteries [16] (electric batteries will be reused, remanufactured or recycled at the end of their life [14]) - figure 8.

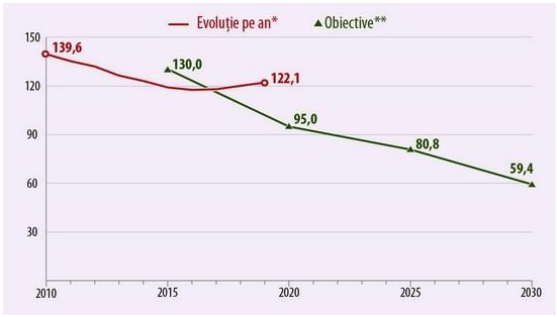

Figure 8 - *Evolution of CO2 emissions from new cars - In gCO2 per km*
**Estimated for 2010, 2011 and 2012*
*** Indicative targets calculated by the European Environment Agency (EEA) according to EU Regulation - 2019/631*
Source: Eurostat (sdg_12_30); European Environment Agency (EEA), 2021

So in 2021 the European Commission has proposed to reduce the emissions threshold for cars by 55% and for vans by 50% by 2030, and to reach zero emissions by 2035.

In this context, the European Parliament adopted on 10 March 2022 a report that the life cycle of a product, from design to consumption to recycling into components for new products, will be permanently controlled. The Parliament's Environment Committee also approved (in May 2022) a target of zero emissions by 2035.

In this context, we point out that on 24 June 2021 Parliament adopted the European Climate Act. This should come with a number of benefits: cleaner air, water and soil, lower energy bills, renovated homes, improved public transport, more charging stations for electric cars, less waste, healthier food and healthier living for current and future generations.

To reduce CO2 emissions and achieve climate neutrality by 2050 according to the European Green Pact roadmap, greenhouse gases need to be reduced by 90% compared to 1990 levels [18].

According to Our World in Data based on the Global Carbon Project (2022) national and global CO2 emissions data are from 1750 [20, 21]. It should be noted that great efforts have been made by various researchers/specialists (including Andres et al. (1999); Etemad et al. (1998)) to reconstruct historical energy statistics. Even if the statistics are less detailed (for the 18th, 19th and first decades of the 20th century) - and for some countries these figures are more uncertain - they provide solid estimates of long-term trends in energy consumption and derived CO2 emissions. Estimates of combined emissions from fossil fuels, industry and land use are included (Figure 9).

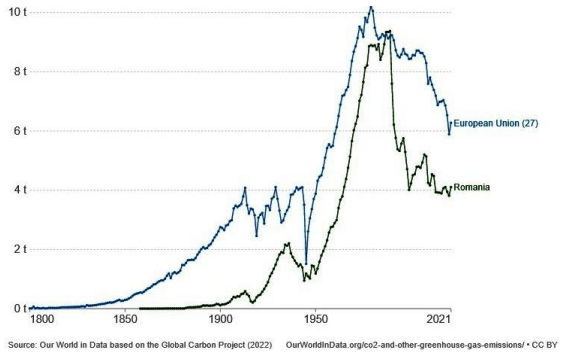

Figure 9 - *Per capita CO_2 emissions Carbon dioxide (CO_2) emissions from fossil fuels and industry1. Land use change is not included*
Source: Our World in Data based on the Global Carbon Project (2022)OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/

Carbon dioxide (CO_2) emissions from fossil fuels and industry as well as land use change are not included.

Note that the European Union (as party to the 1979 Kyoto Protocol and party to the 2015 Paris Agreement) has committed to reduce its greenhouse gas emissions by 40% by 2030 and by 80-95% by 2050. This can be achieved by developing and implementing policies and measures to reduce emissions.

4 Conclusion

In conclusion, we show that environmental concerns have brought electric cars back to the market. The presence of electric cars is primarily due to zero emissions when using an electric vehicle, the low price of electricity compared to diesel or petrol, the bonuses that states are willing to give to those who buy such a vehicle, reduced noise pollution, periodic servicing requires lower maintenance costs throughout the period of operation and electric cars will become even less harmful to the environment if batteries are made more durable.

These issues are based on the requirements for a clean environment at European level. To this end, the European Climate Act was adopted on 2 June 2021, requiring a 55% reduction in emissions by 2030 and the achievement of climate neutrality by 2050. All these requirements aim to achieve certain benefits: cleaner air, water and soil, cheaper energy bills, renovated homes, improved public transport, more charging stations for electric cars, less waste, healthier food and a healthier life for current and future generations. This will lead to jobs in renewable energy, energy efficient buildings and processes. At the same time, the beneficial effects of reducing/eliminating emissions in nature maintain the health of the population.

Acknowledgment

This paper has been financially supported within the project entitled "DECIDE-Development through entrepreneurial education and innovative doctoral and postdoctoral research", project code POCU/380/6/13/125031, project co-financed from the European Social Fund through the 2014–2020 Operational Program Human Capital.

References

1. Amoroso, Francesco Antonio (2014) Eco-Friendly innovation in electricity transmission

and distribution networks, 1 st Edition – November 27, eBook ISBN: 9781782420194
2. Anenberg, S.; Miller, J.; Henze, D.; Minjares, R. (2017), A Global Snapshot of the Air Pollution-Related Health Impacts of Transportation Sector Emissions in 2010 and 2015.
3. Gis, M. (2017), Emisja dwutlenku węgla z transportu drogowego-cz. 1 samochody klasy LDV. Transp. Samoch, www.yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-f035243e-40a4-4055-ae7d-2a65584a9047
4. Hiskey, D. (2011). In 1899 Ninety Percent of New York City's Taxi Cabs Were Electric Vehicles. [online] Today I Found Out.
5. Liu, Y.; Chen, H.; Gao, J.; Li, Y.; Dave, K.; Chen, J.; Federici, M.; Perricone, G. (2021), Comparative analysis of non-exhaust airborne particles from electric and internal combustion engine vehicles. J. Hazard. Mater. 2021, 420, 126626.
6. Mehlig, D.; Woodward, H.; Oxley, T.; Holland, M.; (2021), ApSimon, H. Electrification of Road Transport and the Impacts on Air Quality and Health in the UK. Atmosphere 2021, 12, 1491
7. Milev George, Hastings Astley, Al-Habaibeh Amin, (2021), The Environmental and Financial Implications of Expanding the Use of Electric Cars - A Case Study of Scotland, Journal Pre-proof, www.abdn.pure.elsevier.com/en/publications/the-environmental-and-financial-implications-of-expanding-the-use
8. Pietrzak, K.; Pietrzak O., (2020) , Environmental Effects of Electromobility in a Sustainable Urban Public Transport. Sustainability 2020, 12, 1052.
9. Smeds, E.; Cavoli, C. (2021) Pathways for Accelerating Transitions towards Sustainable Mobility in European Cities; Barcelona Centre for International Affairs (CIDOB): Barcelona, Spain,
10. Our World in Data based on the Global Carbon Project (2022) OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/ • CC BY

Web addresses:
11. www.ac.els-cdn.com/B9781782420101000173/3-s2.0-B9781782420101000173-main.pdf?_tid=8ec36222-150e-11e6-b1da00000aacb360&acdnat=1462706475_6f2dc0e2e96f63589282373fc7937dd3
12. www.autocritica.ro/green-zone/masinile-electrice-cum-functioneaza/
13. www.economictimes.indiatimes.com/news/international/world-news/why-electric-cars-may-not-reduce-pollution / articleshow/66602360.cms
14. www.europarl.europa.eu/doceo/document/ENVI-PR-696435_RO.pdf
15. www.europarl.europa.eu/news/ro/headlines/society/20190313STO31218/emisiile-de-co2-de-la-autovehicule-date-si-cifre-infografic
16. www.europarl.europa.eu/news/ro/headlines/priorities/economia-circulara/20220228STO24218/noi-reguli-ue-pentru-baterii-mai-durabile-si-mai-etice
17. www.europarl.europa.eu/news/ro/headlines/priorities/economia-circulara/20210128STO96607/cum-doreste-ue-sa-obtina-o-economie-circulara-pana-in-2050
18. www.europarl.europa.eu/news/ro/headlines/priorities/schimbarile-climatice/20200618STO81513/pactul-verde-cheia-unei-uniuni-neutre-climatic-si-sustenabile
19. www.jurnalul.ro/bani-afaceri/economia/p-allindustrial-ro-iti-explica-tot-ce-trebuie-sa-stii-despre-motoarele-electrice-873499.html
20. www.mdpi.com/1996-1073/15/7/2703
21. www.ourworldindata.org/explorers/co2?time=earliest..2021&facet=none&country=ROU~European+Union+%2827%29&Gas=CO%E2%82%82&Accounting=Productionbased&Fuel+or+Land+Use+Change=All+fossil+emissions&Count=Per+capita
22. www.proconsilgrup.ro/motoare-electrice/
23. www.scribd.com/document/332576278/Impactul-Motoarelor-Termice-Asupra-Mediului
24. www.theicct.org/sites/default/files/publications/Global_health_impacts_transport_emissions_2010-2015_20190226.pdf
25. www.todayifoundout.com/index.php/2011/04/in-1899-ninety-percent-of-new- york-citys-taxi-cabs-were-electric-vehicles/
26. www.toyota.ro/discover-toyota/environment/cleaner-mobility/fuel-cell
27. www.mașinaelectrica.ro.