

ELECTRICITY IN PUBLIC PASSENGERS' TRANSPORTATION AND THE IMPACT ON CONSUMPTION IN THE NATIONAL ENERGY SYSTEM

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Abstract— *Electric drive systems in mobility solutions are increasingly being used by the manufacturers in the global automotive industry. The European strategy to reduce greenhouse gas emissions to zero by 2050 is also transposed into Romania's Energy Strategy. An important part of this strategy is the use of electricity in public passenger transport to significantly reduce pollution in urban areas. The rapid pace in terms of the renewal of conventional urban transport with modern electrified solutions requires, at the same time, an analysis of the pressure that this new consumer can exert on the national energy system.*

Keywords — Electricity, pollutant emissions, electric bus, public transport, energy consumption, National Energy System.

I. INTRODUCTION

In the context of climate change in recent decades caused by the global warming, the European Commission developed in 2020 – the strategy for sustainable mobility and intelligence, which aims to achieve a sustainable, smart and resilient European transport system. The strategy aims to reduce transport-related greenhouse gas emissions by 90% by 2050 to make Europe the first green continent. To achieve this goal, the transition to a greener, more sustainable, and smarter mobility system is needed.

Transport accounts for 25% of the EU's total polluting and greenhouse gas emissions. The strategy sets a gradual reduction in pollution and the first target is a 55% reduction by 2030, which requires a lot of ambition and an important effort in modernizing transport.

Electric drive systems will be integrated into mobility solutions and the European strategy sets specific targets for 2030, 2035 and 2050 in terms of the transition to the clean transport:

By 2030:

- At least 30 million zero-emission vehicles will be in operation on European roads.
- More than 100 European cities will be climate neutral.
- High-speed rail traffic will double across Europe.
- Automated mobility will be widely implemented.
- Zero-emission shipping will be ready for sale.

By 2035:

- Large zero-emission aircraft will be ready for commercial use.

By 2050:

- Almost all cars, vans, buses, and new heavy-duty vehicles will have zero emissions.
- Rail freight traffic will double.
- A fully operational, multi-modal trans-European transport network (TEN-T) for sustainability and intelligent transport with high-speed connectivity.

II. ELECTRIC BUS IN URBAN TRANSPORT

With regard to Romania, previous studies have shown that a sudden transition toward electrification of transport is virtually unsustainable given the pressure that would be exerted on the national energy system (NES) correspondingly a more than 11 times higher consumption need than the average production capacity.

At present, there is a great interest at national level in purely electric transport, especially in urban areas, due to the fact that the autonomy of electric vehicles (with one charge) is still low and is much better suited for short distances or in urban crowded traffic. Electric cars have a number of advantages such as significant reduction in pollutant emissions, cost of operation, cost of electricity compared to traditional fuels, zero taxes and taxes, access to European funds, support measures such as the „rabla program” but also a number of disadvantages such as high purchase price, low autonomy, still poor charging station infrastructure, longer charging times.

In 2018, the transition of classical urban passenger transport to electrified transport began. If over 50 electric buses were purchased at national level in the first 2 years, since 2021 several auctions have been conducted at the initiative of both local authorities and central authorities through the Ministry of Development. More than 21 cities are targeted, which by the end of 2023 would have more than 500 new purely electric buses. The aim is to gradually renew the current fleet of polluting buses with zero pollution buses with a view to drastically reducing pollution in large urban agglomerations in line with the EU Strategy for sustainable Mobility and Intelligence, Romania's Energy Strategy 2020-2030 and the Integrated national Plan for Energy and Climate change 2021-2030.

On the other hand, the increased interest in electrified public transport is also explained by the fact that sources of financing can be accessed from non-reimbursable European funds that are available for energy efficiency projects, reducing pollution and increasing the quality of life in cities while polluting buses do not provide investment funds.

Public transportation is the business card of a city and shows the degree of civilization. Most importantly, public transport plays an extremely important role in reducing pollution and streamlining traffic. In a city that has a well-established public transport, with modern, clean vehicles that come on time, people give up their personal car, which translates into less crowded traffic and cleaner air.

Now in Romania there are about 5146 urban buses and minibuses of different sizes and powers operating within public passenger transport companies. They are equipped with combustion engines using polluting fuels and will be gradually replaced in the coming years with clean alternatives.

The transition to the purely electric bus creates a new consumer typology of the NES alongside other means of transport already existing in the urban environment such as trams and trolleybuses. If in the case of trams and trolleybuses the electricity consumption in the network is instant while the vehicles operate on the routes and run between 05:00-00:00 in the case of buses equipped with electric batteries where the electricity is stored, the charging periods and consumption in the NES are estimated to be between 13:00 and 05:00 with peak consumption periods in the period when they are immobilized outside the working hours respectively 00:00-05:00.

In order to assess the maximum impact of this consumer, it is necessary to construct an absolutely negative charging scenario ("worst-case") in which the entire urban bus fleet would be hypothetically coupled to the national electricity grid.

The aim is to observe the modeling of energy load curves in different time intervals and comparative analysis of the potential of production versus consumption.

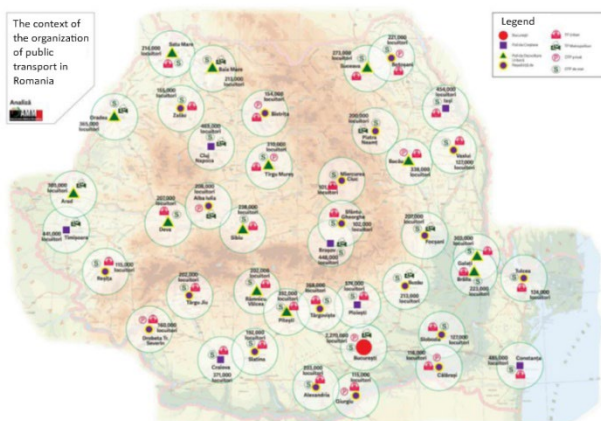


Figure 1. Map of public passenger transport operators in Romania

III. NATIONAL ENERGY CONSUMPTION

Recent studies conducted over a longer period of time have shown that although there is an increase in consumption compared to the beginning of 2000, the current consumption trend cannot be accurately predicted although several elaborate scenarios are periodically constructed, based on detailed statistical data on the consumption structure of production and external trade.

The energy consumption/production balance forecast may be diverted by some variables that cannot be taken into account in the initial calculation, such as climate factors, the lack of clear projections on the implementation of energy efficiency measures and the development of production capabilities or the modernization for the existing ones.

On top of all this are added other variables that are impossible to predict, such as geopolitical movements at the global level and their effects on the global market of conventional resources (natural gas, oil, coal, etc.) which in the context of recent liberalization of the energy market produces shock waves in all sectors of activity with a direct impact on the well-being of the population.

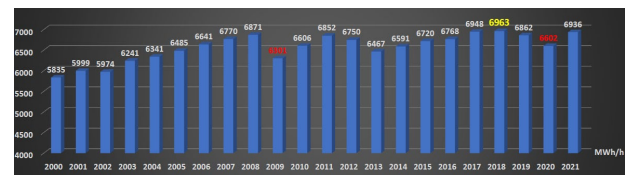


Figure 2. The evolution of the average gross electricity consumption in NES in the period 2000-2021

In regard to the share in the NES of the electricity consumption realized by the electrified urban bus fleet in the hypothetical scenario mentioned above, this value can be determined purely speculatively given the multitude of factors that must be taken into account, for example, the extremely diverse power range from 100kWh to 600 kWh installed on various urban bus configurations.



Figure 3. Case study – TPL Suceava

In order to determine hourly consumption to be taken as a reference, the electricity consumption of the urban bus park in Suceava city was analyzed. The buses are equipped with asynchronous electric motors and a

capacity stored in batteries of 370 kWh. The electricity consumption of an electric bus depends on operating conditions such as the external temperature, the number of passengers transported, the configuration of the route, the number of kilometers traveled, connected consumers (heating, cooling, etc.), all of which influence the electricity needs.

The consumption situation for February was analyzed given that the temperatures in that period are lower and the electric heating system is used to ensure the optimal temperature in the passengers' compartment. On average, one bus made a run of 130km/day, 201kWh/day and a total consumption of 5640kWh/month.

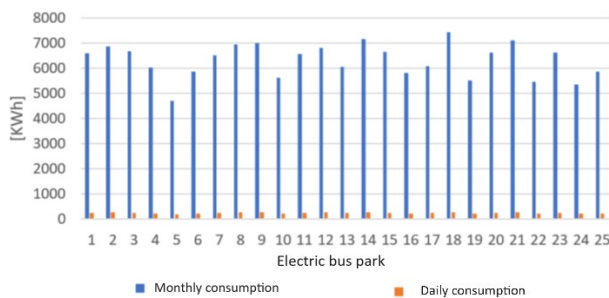


Figure 4. Realized monthly consumption (February 2022)

The consumption of a bus coupled to a slow charging station was 48.29kWh and 0.05MWh respectively. At a simultaneous charging of the 25 buses which is likely between 00:00 and 05:00 the total consumption would be 1.2MWh. Although there are several types of charging stations with different capacities and charging times, we will consider that slow charging stations are used to determine a maximum national consumption.

In the hypothetical scenario, if all the urban electric buses and minibuses in Romania, respectively the 5146 units, were connected to the network, it could generate a consumption of about 250MWh. Compared to the average gross hourly consumption in 2021 of 6936MWh this consumption has a share of only 3.6%.

Although the number of buses used in the hypothetical scenario is purely indicative, the actual number required may be 20-30% higher due to the need to ensure autonomy for a full working schedule, however, it is highly unlikely that the entire park will be in a state of charge at some point in time. Thus, the value already determined for the existing park will be used in the analysis of the energy consumption curve on a given day with a focus on hourly intervals of interest when the maximum consumption can be realized.

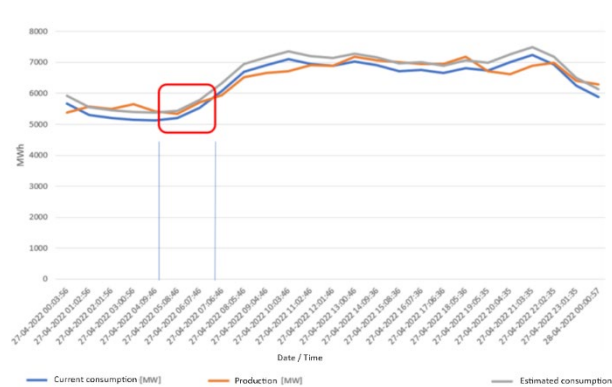


Figure 4. Load curve in 24 hours (Current consumption / Production / Estimated consumption)

A calculation of the load curves in both scenarios, real and estimated, was made for any day on 28.04.2022. The average real gross consumption in NES was 6308.85MWh and the average production covered this consumption being 6474 MWh. By adjusting the consumption curve to the 250MWh generated by the electric bus fleet, several points were identified during the night when production was exceeded by the contribution of the new grid consumer.

Production in the NES traditionally is fluctuating and largely depends on wind and hydro energy instability that can change the allure of the load curve during the chosen observation period, i.e., at night. In the present case, the new consumer in the hypothetical scenario tilts the balance between 4:00 and 7:00 but in an insignificant, yet valuable way.

Statistical data at the level of 2020 showed that around 7.2 million cars are registered in Romania, most of which circulate in cities. Of this total in Bucharest alone there are 1.15mil per population of 1.8m inhabitants. If in the case of buses and minibuses used in urban passenger transport the input data for consumption calculations are easier to establish in the case of passenger cars are several vehicle configurations and various options for charging stations where the charging powers can be from 3.6kWh to 150kWh. Charging can also be done at a normal outlet, but the power is only 2.3kWh for circuits sized at 10A and 3.7kWh for circuits that support a voltage of 16A. Charging times also vary depending on the load power.

A scenario can be built again considering only Bucharest, which would have a 1.15million electric park of cars plugged into a 220V power outlet during the night, with a charging power of 3.7kWh and if there were an appropriate logistics solution.

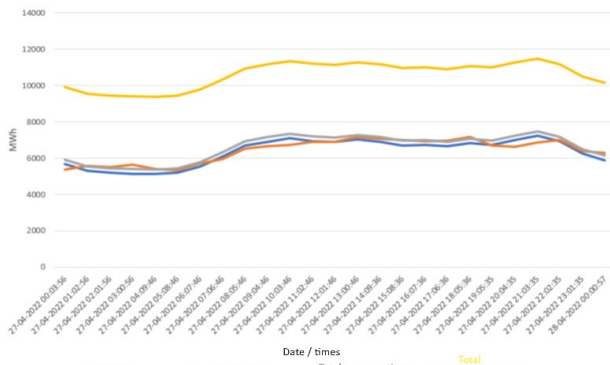


Figure 5. Load curve in 24 hours (Current consumption / Production / Total consumption + buses / Total consumption + cars)

In such a load curve scenario, the maximum production potential of the system would be exceeded by more than 65% on average in relation to level 2018 when it was registered.

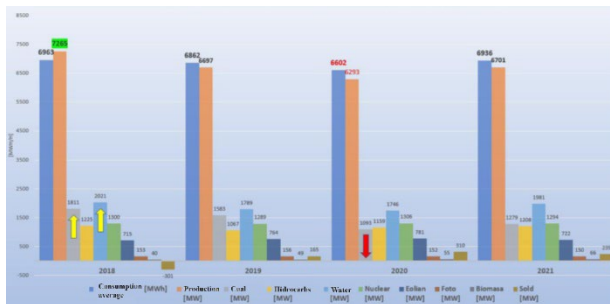


Figure 6. Variation of consumption versus production (2018 - 2021)

IV. ENVIRONMENTAL IMPACT

Road traffic is the most widely used type of transport for both people and goods. Its impact on the environment consists of: Consumption of energy resources (fuels), emissions of air pollutants occupying the space with transport routes, noise pollution, causing serious hazards for man and the environment caused by the lack of security of transport of people and goods or by the content of transported goods (flammable, toxic substances).

Urban traffic is a linear source of low-altitude emissions of pollutants such as: Carbon dioxide, carbon monoxide, nitrogen oxides, sulfur oxides, dust, lead, volatile organic compounds.

Road traffic is increasingly affecting the environment by increasing the number of vehicles. The streets-built decades ago no longer correspond in terms of carrying capacity or in terms of geometrical elements in the plane and in cross profile to ensure the passage of the current volume of traffic. Another aspect is energy efficiency and reducing the consumption of exhausting primary materials. At European level, and implicitly at local level,

there is a continuing concern for reducing greenhouse gases.

The measures are mainly aimed at major cities where the pollution problem is acute.

Electrification of transport is one of the measures adopted and has a direct environmental benefit as polluting gases are completely eliminated. Along with the transition to clean transport, other measures are envisaged such as reducing the number of personal cars in cities, encouraging the use of public passenger transport, modal interconnection solutions, the use of artificial intelligence in urban traffic fluidization solutions, autonomous vehicles, ride sharing, car sharing.

V. CONCLUSIONS

- Regarding the current fleet of buses and minibuses equipped with classic engines, the transition to modern electrified public transport is a viable solution with little impact on the NEs but with an important contribution to reducing greenhouse emissions.

- Urban passenger transport must be modern, clean, intelligent, well organized and attractive to increase usage.

- Complementary measures are needed to reduce the number of polluting vehicles in the urban environment and encourage the use of public passenger transport to the detriment of the use of personal cars that contribute most to urban pollution and traffic congestion.

- Intelligent mobility solutions require faster development and faster deployment.

- More efforts and stronger measures are needed to steer investment in research to develop existing technologies, find more efficient and efficient solutions in terms of the energy performance of road transport.

- Although the electricity production in the NEs is comparable to the consumption in the last 3 years, it failed to cover the consumption so that we borrowed from outside to be able to provide the domestic needs. The projects for the development of new renewable energy production capacities (solar, wind, hydro) have a timid applicability, lagging in the context in which energy security is increasingly needed both nationally and regionally.

- The development potential of projects aimed at capturing solar energy through photovoltaic panels is huge and can be extended to both the industrial area and the residential area through specific programs. There are programs such as "Green House" that encourage the installation of these panels by individuals, but the implementation process is very difficult and takes years and the number of pro-summers beneficiaries is small. In the urban environment, the photovoltaic installation has several benefits such as electricity production, heat absorption and ultraviolet, respectively, reduces the temperature in the urban environment, which is a very beneficial aspect from the point of view of pollution and people's comfort.

REFERENCES

- [1] Planul Național Integrat în domeniul Energiei și Schimbărilor Climatice 2021-2030.
- [2] Strategia energetică a României 2020-2030, MINISTERUL ENERGIEI.
- [3] Sustainable and Smart Mobility Strategy, European Commission.
- [4] N. VASILE, C.I. SALISTEANU, OTILIA NEDELCU, I. ISTUDOR SYSTEMIC ANALYSIS FOR THE USE OF RENEWABLE SOURCES OF ENERGY FOR THE ELECTRIC AUTOMOBILE. CASE STUDY FOR ROMANIA, Scientific Bulletin of the Electrical Engineering Faculty Year 19 No.1 (40) ISSN 2286-2455, DOI: 10.1515/SBEEF-2019-0012.
- [5] https://www.economica.net/harta-oraselor-din-romania-unde-vor-circula-autobuzele-electrice_168972.html
- [6] <https://www.transelectrica.ro/>
- [7] <https://stbsa.ro/statistici>.
- [8] <https://www.macleans.ca/society/technology/no-charging-spots-and-a-strained-electrical-grid-welcome-to-the-electric-vehicle-boom/>