Environmental impact assessment for electric vehicles

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Abstract. In recent years we have observed a significant increase in the number of cars in use. Most of them are vehicles powered by liquid fuels. Unfortunately, with the increasing intensity of car use, the amount of pollution generated in the transport sector is also increasing. In order to reduce the harmful impact on the environment, multi-track actions are necessary to reduce emissions from burning liquid fuels. One of such actions is presented concept of the operation of electric vehicles on the example of a local businessman and determination of ecological assessment indicators for the analysed solution. The simulations demonstrate that the changes in the transport fleet of the local enterprise will not bring about a reduction in pollution, but on the contrary, it will increase the total emission of pollutants by about 20%. This is due to the fact that electric energy for battery charging comes mainly from burning fossil fuels in domestic conditions. A positive impact on the environment was observed only when electric vehicles were powered from a specially selected photovoltaic installation dedicated to the needs of the customer working in a mixed system. The introduction of the electromobilical fleet in connection with the investment in PV installations allowed to avoid CO$_2$ emissions by 44 Mg per year.

1. Introduction
All countries forming the European Union must fulfil the obligations arising from Directive 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of atmospheric pollutants. In this respect, Poland has declared a pollution reduction for two periods, the first of which covers the years from 2020 to 2029 and the second from 2030. During this period, the emission reductions should amount to 59% and 70% for SO$_2$, 30% and 39% for NO$_x$, 25% and 26% for NMLZO, 1% and 17% for NH$_3$ by and 16% and 58% for PM2.5. 2005 was used as a reference point for determining the degree of pollution reduction.

Achievement of the assumed objectives is possible only through consistent implementation of the undertaken actions and close cooperation within the individual source sectors.

From the information published in the report of the National Emissions Balancing and Management Centre \cite{1}, or other literature items \cite{2-6}, it appears that the transport sector, including road transport in particular, is a source of increased air pollution. This sector is a source of about 39% of NO$_x$ emissions, 37% of BC (soot) dust or 23% of CO$_2$. The problem in question is particularly visible in large, densely populated agglomerations where the annual average concentrations of pollutants very often exceed the permissible level \cite{7-9}.

In order to reduce the harmful impact in the road transport sector, in addition to legislative solutions introducing standards for the combustion of fuels in engines, and the development of road infrastructure, there is to be implemented an Electromobility Development Plan "Energy for the Future", adopted by the Council of Ministers on 16 March 2017, which describes the main assumptions, objectives, mechanisms and effects of the large-scale introduction of electric vehicles, the aim of which is to achieve 1 million electric cars by 2025.
Large-scale electromobility encounters many problems [10-14]. Replacing internal combustion engines with electric motors itself will not solve the problem, as the energy for driving means of transport still comes from the combustion of fossil fuels. This problem is particularly visible in Poland, because currently about 70% of electricity is obtained from the combustion of solid fuels. By using electricity from the power grid locally, we are reducing polluting emissions, however because of the source of its origin on a global scale, we are still emitting too much pollution. The available literature presents various ways to reduce emissions generated by road transport: these include the development of public transport [2], a return to rail transport [3], and a change of fuel [6, 5]. Any way to reduce emissions generated by transport in the current state of the art is equally likely. Therefore, in this paper, it was decided to carry out a research to develop a concept for the operation of electric vehicles for the local bakery and to set environmental assessment indicators for the solution under consideration. The aim of this study was performed on the basis of a simulation, in which the option of replacing combustion vehicles used in the bakery with electric vehicles, which will be powered from a specially selected photovoltaic installation dedicated to the customer's needs, was adopted.

2. Characteristics of the test facility
In the company under investigation, the transport of goods was conducted by means of two vans (Crafter 35), twice a day from 4:30 to 7:30 and from 16:00 to 19:00 for 6 days a week. The company also has one Van (Dobo Cargo Standard), which delivers any missing or additional orders not specified in the schedule. In addition, the company employs a sales representative to whom it provides the car (Nissan Micra) for working hours, i.e. between 7:00 a.m. and 3:00 p.m. In the current structure, all vehicles are powered by internal combustion engines.

3. Research results
In the first stage of the study, action has been taken to select electric cars that will be able to meet the requirements. The selection of cars was not guided by the range given by their manufacturer, but by the results of tests of electric cars under WLTP and Autobest conditions. For further analysis, electric cars with similar parameters to vehicles with internal combustion drive, i.e: e-crafter 35, e-NV200 and Nissan Leaf.

When choosing electric transport, it will also be necessary to purchase a vehicle charging station. The basic criterion for the selection of chargers was the speed of their operation so that they could be effectively charged during the interval between successive cycles (Table 1).

| Table 1. Setting the available charging times for vehicle batteries |
|---------------------------------------------------------------|
| Charging time 50kW   | e-Crafter 35 | e-NV200 | Leaf |
|----------------------|--------------|---------|------|
| Charging time 6,6kW  | 7 h          | 7.5 h   | 7.5 h|
| Available time for cargo holds | 2 x 8.5h | 16h     | 16h  |
| Hours in which charging can take place | 19:00-4:30; 7:30-16:00 | 16:00-8:00 | 15:00-7:00 |

The above data shows that it is not necessary to invest in 50 kW fast chargers. For the operation of all four vehicles it will be necessary to purchase 3 stations. A passenger car and a van can be charged from one station due to a 16-hour break. Based on the information gathered so far, an estimation of the electricity required to charge the vehicles has been started (Table 2).
Table 2. Energy demand of electric vehicles

|                      | e-Crafter 35 | e-NV200 | Leaf |
|----------------------|--------------|---------|------|
| Battery capacity [kWh] | 35.8         | 40      | 40   |
| Loads per 24 hours    | 4            | 1       | 1    |
| Daily energy demand [kWh] | 143.2       | 40      | 40   |
| Number of working days per week | 6          | 6       | 5    |
| Total daily demand [kWh]   |              | 223.2   |      |
| Annual energy demand [kWh] | 44 678     | 12 480  | 10 400 |
| Total annual demand [kWh] |              | 67 558  |      |

At the next stage of the simulation, a dedicated photovoltaic installation was selected. The operating schedule of the means of transport enables some of the generated electricity to be consumed on site (the charging period of two vans between 7:30 and 16:00), i.e. 30 000 kWh, i.e. the energy generated from the panels will not be fed into the power grid, but will be transferred directly to the batteries. However, it is not certain that the energy from the sun will allow the batteries to be fully charged every day. It is therefore assumed in the calculations that real time energy consumption will be 1/3 and that the rest of the energy will be taken from the grid at a loss of 30%. This level will be verified once the power of PV power plants has been determined, because it is based on the ratio of the power of chargers to the power of PV power plants. For further analysis, it is therefore presumed that the annual electricity demand from PV installations will be 77 320 kWh.

The PV micro-installation will be located in the Małopolskie Voivodship, where the average capacity of the photovoltaic installation is 950 kWh/kWp. The indicator method described in the relation was used to select the power of the installation.

\[ P_{pv} = \frac{E_{pv}}{\eta_{pv}} \]  

where:
- \( P_{pv} \) - installation power [kWp];
- \( E_{pv} \) - annual electricity demand from PV installations [kWh];
- \( \eta_{pv} \) - efficiency of PV installations [kWh/kWp].

It follows from the above dependence (1) that the power of PV installations should be 81.39 kWp. An important aspect is that in order to be able to account for energy as a prosumer, an installation must be divided into two separate meters, as the total capacity of the required installation exceeds 50kWp. It is therefore necessary to divide the installation into two separate systems, in this case one 30 kWp system will operate in a semi-autonomy with a blockage of excess discharge into the grid and the other 50 kWp system will be connected to the grid. Such a system of PV power plants will allow for maximum use of the resources of PV power plants, while meeting the requirements of the prosumer programme.

Environmental analysis

Based on the information collected on the operation of vehicles in the company, an estimation of the level of pollutant emissions from individual means of transport was started. The results of the analysis are presented in tables 3 and 4.

Table 3. Emissions CO\(_2\) in the variant of combustion vehicles

|                      | Crafter 35 | Dobo Cargo Standard | Micra |
|----------------------|------------|---------------------|-------|
| Average mixed cycle CO\(_2\) emissions [g/km] | 192.5      | 134                 | 133.3 |
| Annual mileage [km]  | 162240     | 43680               | 52000 |
| Annual CO\(_2\) emissions [kg]  | 31231      | 5853                | 6931  |
| Total CO\(_2\) emissions [kg]   |            | 44015               |       |
Table 4. Emissions CO$_2$ of the variant of electric cars charged from the national energy system

| Emission factor CO$_2$ in electricity production for the end user [kg/MWh] | e-Crafter 35 | e-NV200 | Leaf |
|------------------------------------------------|--------------|--------|------|
| Annual electricity demand [kWh]                     | 44678        | 12480  | 10400|
| Annual CO$_2$ emissions [kg]                        | 34760        | 9709   | 8091 |
| Total CO$_2$ emissions [kg]                         | 52560        |        |      |

The CO$_2$ emission factor for the production of electricity for the end user included in the study is given after the report of the National Centre for Balancing and Emissions Management [1]. The analysis which has been conducted so far demonstrate that in the variant in which electric cars are charged with electricity from the public network, the reduction of CO$_2$ emissions is not limited on a global scale; on the contrary, in the case under analysis, such fleet replacement will result in an increase in CO$_2$ emissions of less than 20% in the national variant. The use of electric cars locally makes it possible to avoid pollutant emissions, which is very important for the local community. Supporters of electric cars may blame these analysis for the fact that the greatest weakness of these analysis is that pollutants related to the extraction and distribution of liquid fuels were not taken into account. Of course, this opinion can be shared, but the analysis did not take into consideration the environmental burden resulting from the exploitation of mines and the transport of raw materials to power stations or the production of PV panels. The aim of this work is to draw the recipient's attention to the fact that simply putting electric cars into operation will not solve the problem of environmental protection. Much broader measures are needed.

One of these is the use of renewable sources to obtain the energy needed to power electric vehicles. This will make it possible to reduce CO$_2$ emissions in this case by 44 Mg per year.

4. Conclusion

The analysis of the introduction of an electromobility programme under Polish conditions, based on the example of the transport fleet of a small local company operating in Małopolska, shows that the programme itself will not bring about a reduction in pollution, but on the contrary will result in an increase in total emissions. The electromobility programme itself can only reduce local emissions, at the cost of increasing emissions from the national energy system. The increase in total emissions will be less than 20% in relation to emissions from liquid fuels burned in engines. Electromobility activities under the conditions of the national energy system will contribute to the increase in emissions, and it will be impossible to achieve the objectives of Directive 2016/2284 of the European Parliament and of the Council of 14 December 2016, without the support of local PV power plants. The example of a small company, which by introducing an electro-mobile fleet in conjunction with an investment in PV installations will allow the avoidance of CO$_2$ emissions by 44 Mg per year, which is already a satisfactory effect, given that the operating costs of these installations remain with small businesses, and the energy system can still obtain up to 30% of the energy produced from PV.

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