Applicability of energy storage units to electric transport

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Abstract. The paper analyzes the possibility for replacement hydrocarbon fuels by energy storage devices in transport. The technical characteristics of the modern batteries and ultracapacitors are presented, their specific parameters are estimated. Energy and power requirements for various driving styles of the vehicles are estimated. The determination of requirements for energy storage devices and the evaluation of applicability of energy storage units are demonstrated in the article.

1 Introduction

The generation and consumption of energy can be divided in time by energy storage device. The electrical energy, to date, does not accumulate in large quantities. The use of energy storage devices will make it possible to equalize the load schedule of power plants, i.e. focus them on the average consumption, and make the process of electricity generation more efficient and profitable [1–7].

At present, the development of higher energy density devices includes the participation of vehicle manufacturers. The idea of replacing hydrocarbon fuel with electric energy has been existing for a long time. It is assumed that the embodiment of this idea will not only make the city's air purer, but also will increase the efficiency of using energy resources for the transport movement [8–17].

The information concerning modern energy storage devices as well as the conducted analysis of their specific energy and power parameters allows us to determine the level of the technology development [33-37]. Due to the increasing interest towards electric vehicles, the possibility of using energy storage devices in transport is discussed [38-41].

2 Methodology

To assess the applicability of energy storage units to electric transport, the data were collected on the technical characteristics of two types of storage devices: a lithium-ion battery and an ultracapacitors (or an electrochemical capacitor). Lithium-ion batteries offer a larger value

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for EMF and specific capacity than other. Therefore, this type of battery, at present, is widely used. Ultracapacitors are considered as devices capable to combine the positive characteristics of accumulators and capacitors. The data of currently produced energy storage devices are presented in Table 1.

Table 1. Battery products. The manufacturers’ data.

| №  | Company       | Product               | Nominal Capacity, A*h | Nominal Voltage, V | Max Discharge Current, A | Nominal Discharge Current, A | Max Charge Current, A | Nominal Charge Current, A | Cycle Life (to 80% initial capacity), *10³ | Weight, kg |
|----|---------------|-----------------------|-----------------------|-------------------|--------------------------|-------------------------------|-------------------|--------------------------|---------------------------------------------|------------|
| 1  | Altair Nano   | LTO battery cell      | 66.8                  | 2.2               | 500                      | 2C                           | 500               | 2C                       | 25³                                                       | 1.81       |
| 2  | Samsung SDI   | NCM 111 battery cell  | 94                    | 3.68              | 94                       | 0.3C                         | 47                | 0.3C                     | 3.2                                                       | 2.06       |
| 3  | BYD           | B-Plus 2.5(LFP)       | 50                    | 51.2              | 94                       | 0.5C                         | 47                | 0.5C                     | 6                                                        | 38         |
| 4  | LG chem       | RESU6.5 NMC           | 126                   | 51.8              | 81                       |                               |                   |                          |                                                            | 52         |
| 5  | Victron energy| LFP-Smart 12,8/300    | 300                   | 12.8              | 2C                       | 1C                           | 2.5C              | 0.5C                     | 5                                                        | 51         |
| 6  | BJEV          | LFP-80                | 80                    |                   |                          |                               |                   |                          |                                                            |            |
| 7  | BJEV          | NCM 42                | 42                    |                   |                          |                               |                   |                          |                                                            |            |
| 8  | CATL          | LFP 120               | 120                   | 3.2               | 2C                       | 1C                           | 1C                | 1C                       | 1C                                                        | 2.8        |
| 9  | CATL          | LFP 50                | 50                    | 3.2               | 3C                       |                               |                   | 5.2C                     |                                            | 1.5        |
| 10 | CATL          | LFP92                 | 92                    | 3.2               | 1.5C                     |                               |                   | 3.2C                     |                                                            |            |
| 11 | CATL          |                       | 86                    | 19                | 1C                       |                               |                   |                          |                                                            | 15         |
| 12 | CATL          |                       | 86                    | 28                | 1C                       |                               |                   |                          |                                                            | 22         |
| 13 | CATL          | NCM 37                | 37                    | 3.65              | 3C                       |                               |                   | 1C                       |                                                            |            |
| 14 | CATL          | NCM 72                | 72                    | 3.65              | 2C                       |                               |                   | 1.5C                     |                                                            |            |
| 15 | CATL          | NCM 43                | 43                    | 3.66              | 4C                       |                               |                   | 4C                       |                                                            |            |
| 16 | CATL          | LFP 120               | 120                   | 3.2               | 2C                       | 1C                           | 1C                | 1C                       | 2C                                                        | 2.8        |
| 17 | A123 Systems  | 22S3P NMC             | 78                    | 80.3              | 465                      |                               |                   | 150                      |                                                            | 42.4       |
| 18 | Liotech       | LT-LFP 270            | 270                   | 3.2               | 3C                       | 0.2C                         | 2C                | 0.2C                     | 3                                                        | 9.5        |
| 19 | Liotech       | LT–LFP 770P           | 770                   | 3.2               | 3C                       | 0.5C                         | 3C                | 0.5C                     | 3                                                        | 26.5       |
| 20 | Tesla         | Powerwall             |                       |                   |                          |                               |                   |                          |                                                            | 125        |
Table 1. Battery products. The manufacturers’ data. (cont.)

| №  | Price, €. | Energy, W*h | Specific Energy, W*h/kg | Energy Density, W*h/L | Power, W | Specific Power, W/kg (discharge/charge) | Power Density, W/L (discharge/charge) | Dimensions (WxDxH), mm |
|----|-----------|-------------|-------------------------|----------------------|---------|-----------------------------------------|---------------------------------------|-------------------------------|
| 1  | 148¹      | 51.8¹       | 174¹                    | 2330/4580            | 1290/2350² | 2740/5390²                              | 256x12.6x263                      |
| 2  | 350       |             |                         | 1102⁴                |         |                                         | 173x45x125                         |
| 3  | 1265      | 2450        |                         | 2500                 |         |                                         | 483x490x130                        |
| 4  | 3675      | 6500        |                         | 4200                 |         |                                         | 452x120x654                       |
| 5  | 3830      | 3840        |                         | 265x425x347          |         |                                         |                                      |
| 6  | 127       | 297         |                         |                     |         |                                         |                                      |
| 7  | 180       | 415         |                         |                     |         |                                         |                                      |
| 8  | 240       |             |                         |                     |         |                                         |                                      |
| 9  |           |             |                         |                     |         |                                         |                                      |
| 10 |           |             |                         |                     |         |                                         |                                      |
| 11 | 1650      |             |                         |                     |         |                                         |                                      |
| 12 | 2470      |             |                         |                     |         |                                         |                                      |
| 13 |           |             |                         |                     |         |                                         |                                      |
| 14 |           |             |                         |                     |         |                                         |                                      |
| 15 | 180       | 415         |                         |                     |         |                                         |                                      |
| 16 |           |             |                         |                     |         |                                         |                                      |
| 17 | 6350      |             |                         |                     |         |                                         |                                      |
| 18 | 370       |             |                         |                     |         |                                         |                                      |
| 19 | 740       | 93          | 154,2                   |                     |         |                                         |                                      |
| 20 | 13500     | 5000        |                         |                     |         |                                         | 755x155x1150                      |

Compiled from [12, 13, 18 – 27].

¹70A discharge, 25°C. Testing done using a rated capacity of 70 A*h.
²10 sec pulse, 50% SOC (State of Charge), 25°C
³cycle life at 2C charge and 2C discharge, 100% DOD (Depth of Discharge), 25°C
⁴30 sec pulse, 90% SOC (State of Charge), 25°C

As it can be seen from the Table 1, manufacturers present different technical characteristics. For this reason, the calculation of the specific parameters of storage devices was carried out.

Based on Table 1.

Stored energy in a battery is defined as:

\[ W_{bat} = q \times U \]  \hspace{1cm} (1)

Where q is the nominal capacity (A*h) and U (V) is the voltage of battery.

Equations (2, 3) present the specific energy and energy density.

\[ w_{m,bat} = \frac{W_{bat}}{m_{bat}} \]  \hspace{1cm} (2)

\[ w_{v,bat} = \frac{W_{bat}}{V_{bat}} \]  \hspace{1cm} (3)

The power of battery is defined as:
\[ P_{bat} = U \cdot I_{\text{max}} \]  

(4)

Where \( I_{\text{max}} \) (A) is the maximum (or standard) battery discharge current.

Equations (5, 6) present the specific power and power density.

\[ p_{m_{\text{bat}}} = \frac{P_{\text{bat}}}{m_{\text{bat}}} \]  

(5)

\[ p_{v_{\text{bat}}} = \frac{P_{\text{bat}}}{V_{\text{bat}}} \]  

(6)

Where \( m_{\text{bat}} \) (kg) is weight, \( V_{\text{bat}} \) (L) is volume of battery.

**Table 2. Battery products. Specific parameters.**

| №  | Company          | Energy, W*h | Specific Energy, W*h/kg | Energy Density, W*h/L | Power, W  | Specific Power, W/kg | Power Density, W/L |
|----|------------------|-------------|-------------------------|-----------------------|-----------|----------------------|---------------------|
| 1  | Altair Nano      | 146.96      | 81.19                   | 173.23                | 1100.00   | 607.73               | 1296.66             |
| 2  | Samsung SDI      | 345.92      | 167.92                  | 355.47                | 1100.00   | 607.73               | 1296.66             |
| 3  | BYD              | 2560.00     | 67.37                   | 83.21                 | 1280.00   | 33.68                | 41.60               |
| 4  | LG chem          | 6526.80     | 137.14                  | 237.04                | 768.00    | 274.29               | 474.07              |
| 5  | Victron energy   | 3840.00     | 75.29                   | 151.17                | 2592.00   | 272.84               | 453.50              |
| 6  | BJEV             | 384.00      | 137.14                  | 237.04                | 768.00    | 274.29               | 474.07              |
| 7  | BJEV             | 160.00      | 480.00                  |                       |           |                      |                     |
| 8  | CATL             | 294.40      | 441.60                  |                       |           |                      |                     |
| 9  | CATL             | 1634.00     | 108.93                  | 152.06                | 1634.00   | 108.93               | 152.06              |
| 10 | CATL             | 2408.00     | 109.45                  | 168.04                | 2408.00   | 109.45               | 168.04              |
| 11 | CATL             | 135.05      | 405.15                  |                       |           |                      |                     |
| 12 | CATL             | 262.80      | 525.60                  |                       |           |                      |                     |
| 13 | CATL             | 157.38      | 629.52                  |                       |           |                      |                     |
| 14 | CATL             | 384.00      | 137.14                  | 237.04                | 768.00    | 274.29               | 474.07              |
| 15 | CATL             | 1634.00     | 108.93                  | 152.06                | 1634.00   | 108.93               | 152.06              |
| 16 | CATL             | 2408.00     | 109.45                  | 168.04                | 2408.00   | 109.45               | 168.04              |
| 17 | A123 Systems     | 6263.40     | 147.72                  | 264.97                | 37339.50  | 880.65               | 1579.60             |
| 18 | Liotech          | 864.00      | 90.95                   | 151.17                | 2592.00   | 272.84               | 453.50              |
| 19 | Liotech          | 2464.00     | 92.98                   | 155.21                | 7392.00   | 278.94               | 465.64              |
| 20 | Tesla            | 13500.00    | 108.00                  | 100.31                | 5000.00   | 40.00                | 37.15               |

It should be noted that the data of battery modules and cells are presented in tables (1, 2, 3). Several modules include, in addition to cells, a cooling system, a monitoring and control system. Therefore, dividing by the total volume and mass of the accumulator, specific parameters were diminished. However, obtained distribution demonstrates, in general, the level of the energy parameters, due to the consideration of a large number of models from different manufacturers.

The characteristics of ultracapacitors are presented in Table 3.
### Table 3. Ultracapacitors. Manufacturers’ data.

| No | Company | Product       | Nominal Capacitance, F | Nominal Voltage, V | Maximum Continuous Current, A | Standard Continuous Current, A | Cycle Life, *10³ | Dimensions (WxDxH), mm | Weight, kg |
|----|---------|---------------|------------------------|-------------------|-------------------------------|--------------------------------|----------------|------------------------|------------|
| 1  | Maxwell | K2 2.7V Series| 3000                   | 2.7               | 210                           | 130                            | 1000           | π60.4x138               | 0.51       |
| 2  | Maxwell | K2 2.85V      | 3400                   | 2.85              | 211                           | 131                            | 1000           | π60.4x138               | 0.52       |
| 3  | Maxwell | K2 3.0V       | 3000                   | 3                 | 210                           | 130                            | 1000           | π60.4x138               | 0.52       |
| 4  | NESSCAP | 3.0V         | 3400                   | 3                 | 225                           | 140                            | 1000           | π60.3x138               | 0.5        |
| 5  | EATON   | XL60         | 3000                   | 2.7               | 143                           |                                 |                | π60.3x138               | 0.52       |
| 6  | SKELCAP | SCHE 3500    | 3500                   | 2.85              |                                | 1000                           | 127x47x47      | 0.391      |

Compiled from [28 – 31].

The result of calculating the specific parameters is presented in the Table 4.

### Table 4. Ultracapacitors products. Specific parameters.

| No | Company | Product       | Energy, W*h | Specific Energy, W*h/kg | Energy Density, W*h/L | Power, W | Specific Power, W/kg | Power Density, W/L |
|----|---------|---------------|-------------|-------------------------|-----------------------|---------|---------------------|-------------------|
| 1  | Maxwell | K2 2.7V Series| 1.46        | 2.86                    | 3.69                  | 524.88  | 1029.18             | 1327.45           |
| 2  | Maxwell | K2 2.85V      | 1.84        | 3.54                    | 4.66                  | 662.80  | 1274.61             | 1676.24           |
| 3  | Maxwell | K2 3.0V       | 1.80        | 3.46                    | 4.55                  | 648.00  | 1246.15             | 1638.82           |
| 4  | NESSCAP | 3.0V         | 1.72        | 3.44                    | 4.36                  | 619.16  | 1238.33             | 1571.09           |
| 5  | EATON   | XL60         | 1.60        | 3.07                    | 4.05                  | 574.99  | 1105.75             | 1459.01           |
| 6  | SKELCAP | SCHE 3500    | 1.43        | 3.65                    | 5.09                  | 514.19  | 1315.06             | 1832.83           |
Based on Table 3.

Stored energy in an ultracapacitor is defined as:

\[ W_{\text{cap}} = C(U_1^2 - U_2^2) = \frac{C((0.8E)^2 - (0.4E)^2)}{2 \times 3600} \]  

(7)

Equations (8, 9) present the specific energy and energy density.

\[ w_{m,\text{cap}} = \frac{W_{\text{cap}}}{m_{\text{cap}}} \]  

(8)

\[ w_{v,\text{cap}} = \frac{W_{\text{cap}}}{V_{\text{cap}}} \]  

(9)

Released power in 10 sec is defined as: 

\[ P_{\text{cap}} = \frac{W_{\text{cap}} \times 3600}{10} \]  

(10)

Equations (11, 12) present the specific power and power density.

\[ p_{m,\text{cap}} = \frac{P_{\text{cap}}}{m_{\text{cap}}} \]  

(11)

\[ p_{v,\text{cap}} = \frac{P_{\text{cap}}}{V_{\text{cap}}} \]  

(12)

Where \( m_{\text{cap}} \) (kg) is weight, \( V_{\text{cap}} \) (L) is volume of ultracapacitor.

After determination of the specific parameters of energy storage devices, it is necessary to estimate energy and power parameters of vehicles. The Table 5 shows the main characteristics of cars with an internal combustion engine (ICE).

**Table 5. Characteristics of cars with ICE**

| No | Car with ICE       | Max. power | Fuel tank | ICE with gearbox | By 0-100 km/h time | Acceleration | Gross vehicle mass | Rolling resistance |
|----|-------------------|------------|-----------|------------------|--------------------|--------------|--------------------|--------------------|
|    |                   | kW | L | kg | kg | L | s | m/s² | kg | N |
| 1  | Mazda6            | 110| 60| 45 | 150| 30| 10.50| 2.65  | 1980| 291.06 |
| 2  | BMW 3             | 100| 60| 45 | 150| 30| 8.90 | 3.12  | 1975| 290.33 |
| 3  | Renault LOGAN     | 75 | 50| 37.5| 150| 30| 11.70| 2.37  | 1600| 235.20 |
| 4  | KIA RIO           | 73.3| 50| 37.5| 150| 30| 12.20| 2.28  | 1560| 229.32 |
| 5  | Volkswagen POLO   | 66 | 55| 41.25| 150| 30| 11.20| 2.48  | 1700| 249.90 |
| 6  | LADA Vesta        | 78 | 55| 41.25| 150| 30| 11.20| 2.48  | 1670| 245.49 |
| 7  | Toyota Camry      | 110| 60| 45 | 150| 30| 11.00| 2.53  | 2100| 308.70 |
| 8  | Audi A3           | 110| 50| 37.5| 150| 30| 8.20 | 3.39  | 1785| 262.40 |
Based on [32].

1The weight \((m_{\text{ICE+gearbox}})\) and the volume \((V_{\text{ICE+gearbox}})\) of ICE with gearbox are assumed equal identical due to the lack of information.

The fuel tank weight with fuel is defined as:

\[ m_{\text{tank}} = V_{\text{tank}} \times \rho_{\text{gas}} \]  \hspace{1cm} (13)

Where \(V_{\text{tank}}\) (L) is the volume of the tank, \(\rho_{\text{gas}} = 0.75\) kg/L is the density of petrol.

The acceleration can be written as:

\[ a = \frac{v_{\text{auto 100}}}{T_{100}} \]  \hspace{1cm} (14)

Where \(v_{\text{auto}} = 100\) km/h is the vehicle speed, where \(T_{100}\) is the acceleration time from 0 to 100 km/h.

The rolling resistance of a car is defined as:

\[ F_{R} = f \times m_{\text{auto}} \times g \]  \hspace{1cm} (15)

Where \(f = 0.015\) is rolling resistance coefficient tires on the asphalt, \(m_{\text{auto}}\) is weight of car, \(g = 9.8\) m/s\(^2\) is gravitational acceleration.

Calculation results of the energy and power, which required at the wheels to drive with constant speed of 60 km/h for 3 h, are presented in the Table 6.

| №  | Car with ICE     | Moving at a constant speed of 60 km/h for 3 h | Acceleration to 60 km/h |
|----|-----------------|---------------------------------------------|-------------------------|
|    |                 | Work / energy expended | Power | Work / energy expended | Time | Power |
| 1  | Mazda6          | 52390.8          | 14.55 | 4.851                | 275.00 | 0.076 | 6.3 | 43.65 |
| 2  | BMW 3           | 52258.5          | 14.52 | 4.839                | 274.31 | 0.076 | 5.3 | 51.37 |
| 3  | Renault LOGAN   | 42336.0          | 12.76 | 3.920                | 222.22 | 0.062 | 7.0 | 31.66 |
| 4  | KIA RIO         | 41277.6          | 11.76 | 3.822                | 216.67 | 0.060 | 7.3 | 29.60 |
| 5  | Volkswagen POLO | 44982.0          | 12.50 | 4.165                | 236.11 | 0.066 | 6.7 | 35.14 |
| 6  | LADA Vesta      | 44188.2          | 12.27 | 4.092                | 231.94 | 0.064 | 6.7 | 34.52 |
| 7  | Toyota Camry    | 55566.0          | 15.44 | 5.15                 | 291.67 | 0.081 | 6.6 | 44.19 |
| 8  | Audi A3         | 47231.1          | 13.12 | 4.37                 | 247.92 | 0.069 | 4.9 | 50.39 |

Based on Table 5.

The work done for uniform motion is defined as:

\[ A_{\text{uni f}} = F_{R} \times S = F_{R} \times v_{\text{auto}} \times T_{\text{trip}} \]  \hspace{1cm} (16)

Where \(F_{R}\) (N) is the rolling resistance, \(S\) is the way, \(v_{\text{auto}}\) (km/h) is the constant speed of the car, and \(T_{\text{trip}}\) (h) is the duration of the trip.
The power for uniform motion can be written as:

\[ P_{\text{unif}} = \frac{A_{\text{unif}}}{T_{\text{trip}}} \]  

(17)

The work done for acceleration can be described using the following equation:

\[ A_{\text{acc}} = \frac{m_{\text{auto}} \cdot v_{\text{auto}}^2}{2} \]  

(18)

The acceleration time from 0 km/h to constant speed is defined as:

\[ T_{\text{acc}} = \frac{v_{\text{auto}}}{a} \]  

(19)

The power for acceleration is defined as:

\[ P_{\text{acc}} = \frac{A_{\text{acc}}}{T_{\text{acc}}} \]  

(20)

Assuming the replacement of the fuel tank, ICE with the gearbox by the energy storage device, i.e. replacement by a similar mass and filling the volume occupied by these elements, the energy storage requirements are determined. The results of this approximate calculation are given in the Table 7.

Table 7. Requirements for energy storage device

| № | Car with ICE     | Energy     | Specific Energy | Energy density | Power  | Specific power | Power density |
|---|------------------|------------|-----------------|----------------|--------|----------------|---------------|
|   |                  | kW*h      | W*h/kg          | W*h/L          | kW     | W/kg           | W/L           |
| 1 | Mazda6           | 28.30      | 145.14          | 314.48         | 43.65  | 223.85         | 485.01        |
| 2 | BMW 3            | 28.23      | 144.78          | 313.68         | 51.37  | 263.43         | 570.76        |
| 3 | Renault LOGAN    | 22.87      | 121.98          | 285.89         | 31.66  | 168.83         | 395.69        |
| 4 | KIA RIO          | 22.30      | 118.93          | 278.74         | 29.60  | 157.86         | 369.99        |
| 5 | Volkswagen POLO  | 24.30      | 127.06          | 285.89         | 35.14  | 183.72         | 413.36        |
| 6 | LADA Vesta       | 23.87      | 124.82          | 280.84         | 34.52  | 180.47         | 406.07        |
| 7 | Toyota Camry     | 30.02      | 153.94          | 333.54         | 44.19  | 226.63         | 491.02        |
| 8 | Audi A3          | 25.52      | 136.08          | 318.94         | 50.39  | 268.74         | 629.87        |

Based on Tables 5 and 6.

The energy accumulated in the energy storage system is defined as:

\[ W_{\text{ESS}} = A_{\text{unif}} + N * S * A_{\text{acc}} \]  

(21)

Where N=1 (1/km) is the number of accelerations.

The power of energy storage system can be written as:

\[ P_{\text{ESS}} = P_{\text{acc}} \]  

(22)

Equations (23, 24) present the specific energy and specific power:

\[ w_{m,\text{ESS}} = \frac{W_{\text{ESS}}}{m_{\text{tank}} + m_{\text{ICE+gearbox}}} \]  

(23)

\[ p_{m,\text{ESS}} = \frac{P_{\text{ESS}}}{m_{\text{tank}} + m_{\text{ICE+gearbox}}} \]  

(24)

Equations (25, 26) present the energy density and power density:
\[ w_{V,E \!SS} = \frac{W_{E \!SS}}{V_{tank} + V_{ICE+gearbox}} \]  
\[ p_{V,E \!SS} = \frac{P_{E \!SS}}{V_{tank} + V_{ICE+gearbox}} \]  

3 Results and discussion

For the analysis of the obtained data, Figures 1 and 2 are presented. They show the distribution of the characteristics of storage devices and the calculated requirements for the energy storage devices. By ‘requirements’ it is meant providing the same energy and power parameters of car by energy storage device like in case of use gasoline as an energy source.

Fig. 1. Energy storage system and cars. Specific energy - specific power.
Comparing the requirements for energy storage system for different driving style (Auto 60 km/h for 3h, Auto 100 km/h for 1h, etc.) with the specific parameters of the batteries and ultracapacitors, an assessment of the use of energy storage units in electric transport is made. So, according to the Figure 1, the considered installation of a battery of some companies will not increase the mass of the vehicle and will meet the energy and power needs when driving at a maximum speed of 60 km/h (Auto 60 km/h 3h) for most vehicles. The Figure 2 demonstrates that the battery will require an additional volume for this purpose. This volume can be obtained by creating an efficient design and structure of the entire battery pack, taking into account the design of the electric vehicle.

The demand for high power, arising during the process of motion, can be satisfied by an ultracapacitor. For this reason, its combined use with the battery has advantages.

Both figures show that, in comparison with the traditional ICE system, the electric storage system is inferior at long range of travel and at a higher speed.

4 Conclusion

Undoubtedly, electric transport is one of the most promising means of transportation and it can be considered as an alternative to traditional transport with an internal combustion engine. The study carried out in this paper demonstrated that modern energy storage units, installed in an electric vehicle, make it competitive for short trips. This kind of trips take place in urban conditions.

As conclusions it is necessary to allocate:
1. There is the possibility of application energy storage units for urban transport, both public and private.
2. It is possible to improve vehicles used in warehouses and industrial premises, as well as in agriculture, requiring a minimum amount of gas emissions. The main reason that prevents the mass implementation of electric vehicles is their high cost. However, there is a downward trend in the cost of the energy storage device and upward trend in the specific energy [12].

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