ELECTRIC VEHICLE TECHNOLOGY IMPLEMENTATION IN STUDIES

Uldis Putnieks, Dainis Berjoza, Inara Jurgena
Latvia University of Agriculture
uldis.putnieks@llu.lv, dainis.berjoza@llu.lv, inara.jurgena@llu.lv

Abstract. Electric vehicles are gaining popularity in Latvia and the learning process at the Latvia University of Agriculture should also follow the newest trends, insuring that students will be able to work with the latest technologies. Electric vehicles: bicycles, scooters and automobiles, can be used instead of internal combustion engine vehicles in the process of learning at the Faculty of Engineering and the Faculty of Economics and Social Development. Complete substitution cannot be done, because fuel consumption and exhaust gasses need to be studied, too. Students find the learning process more interesting working with new technologies and being able to compare them to the current ones. At the Latvia University of Agriculture cooperation between faculties is common, that is why the Faculty of Economics and Social Development uses the Faculty of Engineering laboratories to learn about economy and ecology of electric vehicles. Advantages and disadvantages for electric vehicle implementation in the learning process are discussed. Methodology for economical gain for one laboratory session has been calculated and it is 61.21 %, if the same experiment is carried out with an electric vehicle. A survey was carried out and the results show that the students want to try out electric vehicles, as the biggest advantages they mention no emission gases, cheaper exploitation and quiet movement. As the biggest disadvantages the students draw attention to the short driving range, pricy batteries and the high buying price.

Keywords: electric vehicle technology, Agricultural Engineering studies, zero emissions.

Introduction

Oil resources are not unlimited and also the requirements for exhaust gases demand new technology implementation in automotive industry. More and more alternative resources are gaining popularity. Commonly used biofuels can be divided in plant (for example, rape seed oil) and biodiesel for diesel powered engines and bioethanol for petrol powered engines. There are used also different energy sources – biogas, hydrogen, electricity. There are more and more electric vehicles being introduced, which do not use internal combustion engines. There are only 17 electric automobiles in Latvia by 01.01.2014 and only tree electric-gasoline automobiles according to Vehicle Registration – Road Traffic Safety Directorate of the Republic of Latvia [1].

Historically electricity was competing with internal combustion engines at the beginning of automobile evolution. These vehicles were quiet, without exhaust gasses and hand cranking. However, electric starter and other technical invention introduction and also road network expansion lead to internal combustion engine domination.

With larger student groups there is a problem to do on-road laboratory sessions, because the faculty is in the city centre and to find a straight road with barely any traffic is impossible, so the students need to be transported few miles outside the city, that complicates logistics: to order a bus, to loose time when driving and managing to do the task in the limited left time. So, these trips need to be fewer.

Modern technologies also need to be implemented in the study process. The aim of this research is to analyze electric vehicle implementation and approbation at the Latvia University of Agriculture (LUA), Faculty of Engineering (FE) and the Faculty of Economics and Social Development (FESD) study process.

Materials and methods

LUA FE engineering study programs

The FE organizes several study programs, in which vehicles are used for the learning process. In the bachelor degree:

- Agricultural Engineering with subprograms:
  - Autotransport;
  - Technical and Technological Service;
  - Agricultural Machinery;
  - Entrepreneurship in Agroservice;

  - Animal Breeding Mechanization;
  - Food Engineering;
- Agricultural Energetics;
- Machine Design and Production;
- First level professional higher education program Technical Expert.

The following study programs use vehicles in the master degree:

- Autotransport;
- Machine Design and Production;
- Agricultural Energetics;
- Agricultural Machinery;
- Animal Breeding Mechanization;
- Technical and Technological Service.

Vehicles are used for construction and exploitation studies, also for experiments, for example, to determine the acceleration parameters or engine power.

The courses of study, which use internal combustion engine vehicles that can be substituted with electric ones, are:

- Automobile and Engine Theory;
- Technical Service of Automobiles;
- Automobile Theory for experts;
- Motor Vehicle Construction;
- Motor Vehicle Construction for machine designers;
- Automobile Tire Service and Repair;
- Automobile and Environment;
- Electrical System of Vehicles;
- Design of Autotransport Enterprises;
- Technical Service of Automobiles.

Practical studies for all study courses can be divided in the following directions:

- practical sessions about vehicle construction;
- laboratory sessions about vehicle exploitation;
- laboratory sessions about vehicle exploitation characteristics.

To learn about the vehicle construction in practical sessions, electric vehicles do not need to obligatory have practical models. Of course, the learning process will be more interesting and qualitative, if a practically produced electric vehicle model is used. These models can be related to electric motors, power supply, brake system, power steering and other vehicle components. It is possible to use also other learning methods, for example, posters, videos, presentations and projectors.

The LUA Motor Vehicle Institute (MVI) study courses, which are connected with electric vehicle construction studies, currently use presentations and handouts on paper, in the future cutaway models, for example, transmission and motor, are planned to be used.

The FE MVI implemented the ERAF Project "Usage of Electric Energy in Motor Vehicles of Physical Persons". Rebuild of an internal combustion engine driven automobile to electricity was taking place. After this the rebuilt vehicle will be tested, and could be implemented in laboratory sessions.

Electric vehicles can be used for the following in exploitation connected laboratory sessions:

- automobile braking characteristics;
- automobile shock absorber test;
- automobile wheel alignment;
- automobile wheel montage;
- automobile tire montage and balancing;
- automobile headlight regulation;

- automobile engine power determination on a chassis dynamometer;
- automobile electronics diagnostics.

With automobile exploitation connected laboratory sessions usually are held in specialized laboratories, but on-road experiments are not common.

With automobile exploitation characteristics connected laboratory sessions usually are held in specialized laboratories and also in on-road experiments. Laboratory sessions, in which the exploitation parameters can be measured on an electric vehicle, are:

- automobile mass center determination;
- grip module determination;
- acceleration parameter determination;
- braking parameter determination;
- rolling and air resistance module determination;
- speedometer calibration and speed parameter determination;
- power and torque parameter determination;

Electric vehicle usage in laboratory sessions connected with exploitation has some advantages:

- there are no exhaust gasses during moving inside the laboratory;
- there is no noise, allowing students to hear everything, and work in nearby rooms is not disturbed;
- there is no need to use fuel that needs to be bought, stored and documented;
- energy source is produced in Latvia, because all fuel is imported;
- usage of electric vehicle is cheaper;
- maintenance of the vehicle is cheaper and more easy, no need to change and utilize oil.
- electric vehicle usage in laboratory sessions has some disadvantages:
- there can be situations when the laboratory has heavy schedule and the electric vehicle cannot be fully charged, for example, on a chassis dynamometer;
- extra calculations need to be done in on-road experiments, to accumulate the driving range (usually 100-150 km);
- due to low noise, the driver needs to be extra careful to work in environment with lot of students;
- no laboratory session can be done about exhaust gasses and fuel consumption.

In other study programs

At the LUA cooperation between faculties is common. Other faculties can use the FE material base, for example, the Faculty of Economics and Social Development (FESD) provides few study courses that are about ecology and environmental administration. Study courses that can use electric vehicles in their learning process are:

- Environmental Economics in bachelor level;
- Environmental Economics in master level.

Students in Environmental Economics explore different ways to save environment and also to be able to organize manufacturing that rests on cautious resource usage at the same time.

In practical studies at the MVI FESD students from the study program “Economics” are learning about electric vehicle general advantages and exploitation differences compared to internal combustion vehicles. In practical sessions electric vehicle tests are planned. Depending on a season, the test subject can be an electric bicycle or automobile.

Electric vehicle should be fully charged before the experiments and after the test, at least 30 % of the driving range should be used. After the experiment the students attach the logger and start the charging process. The logger shows the consumed energy, knowing the trip distance, the students can calculate the charging cost, one km cost and compare to analogue internal combustion engine vehicles. The students also can calculate CO_2 emission decrease, presuming that in electricity production $CO_2 = 0$. This presumption is valid if renewable resources are used, 70 % of electricity production in

Latvia is by hydroelectric power stations by Latvenergo Group Sustainability and Annual Report (2011) [2]. The students find this more interesting than ecology calculation, for example, for a factory.

Economical advantages in electric vehicle usage in laboratory sessions

At the FE MVI electric vehicle usage in the learning process has been already approbated. Students did acceleration and braking tests with an electric scooter using a scientific radar. The main advantages for these tests are:

- test needs a short distance, no more than 100 m, it can be carried out in the faculty yard;
- easy communication between the students, no need for walkie-talkie;
- no noise during the experiments;
- no need to go to special experiment road outside the city;
- easy to make experiment repeats because electric vehicles have very stable acceleration parameters.

Tests with electric automobiles could be more interesting for students, but they could be carried out on the same road outside the city, same as internal combustion engine vehicles.

To determine the costs for on-road experiments, expense analysis has to be done. Laboratory session consists of different components:

$$C_{ex} = C_F + C_E + C_R + C_P + C_C, \tag{1}$$

where C_F – fuel or electricity costs for one test series, EUR;
C_E – automobile maintenance costs, EUR·(lab. sessions)$^{-1}$;
C_R – automobile repair costs, EUR·(lab. sessions)$^{-1}$;
C_P –automobile preparation and tiding up job cost, EUR·(lab. sessions)$^{-1}$;
C_C – annual taxes to be able to participate in traffic, EUR·(lab. sessions)$^{-1}$.

Separate members of Formula 1 will be analyzed next. The fuel cost for one experiment series can be calculated:

$$C_F = \frac{l \times Q \times c_f}{100}, \tag{2}$$

where l – managed distance during laboratory session, km;
Q – fuel consumption for particular vehicle, l·(100·km)$^{-1}$;
c_f – price for consumed fuel, EUR·l^{-1}.

If an electric vehicle is used in a laboratory session:

$$C_F' = \frac{l \times Q_e \times c_e}{100}, \tag{3}$$

where Q_e – electricity consumption, kWh·(100·km)$^{-1}$;
c_e – electricity price, EUR·(kWh)$^{-1}$.

The automobile maintenance costs on one laboratory session can be calculated:

$$C_E = \frac{(C_{SP} + C_J)l}{L_V}, \tag{4}$$

where C_{SP} –spare part cost in one maintenance, EUR;
C_J – automobile maintenance work costs, EUR;
L_V – average automobile kilometrage between maintenances, km.

Because automobile repairs are hard to forecast, it is assumed that in Latvia repair costs on average will be 30 % from the maintenance cost for electric and 50 % for internal combustion vehicles. The automobile maintenance costs for 1 laboratory session can be calculated:

$$C_R = C_E \times k, \tag{5}$$

where k – repair coefficient in relation to technical maintenance, accordingly 0.3 for electric and 0.5 for internal combustion vehicles.

The automobile preparation and tiding up job costs before and after laboratory sessions can be calculated:

$$C_P = t_P \times c_m, \tag{6}$$

where t_P – time for vehicle preparation and tiding up, h;
c_m – hourly wage for master of laboratory, EUR·h^{-1}.

The expenses for yearly taxes are calculated:

$$C_C = \frac{C_R + C_{RwT}}{N_L}, \tag{7}$$

where C_R – automobile road tax; EUR;
C_{RwT} – MOT test expenses, EUR;
N_L – laboratory session count for a year in all study courses that use accordant vehicles.

Inserting Formulas 2 – 7 in interconnection 1, Formula for an internal combustion engine vehicle is:

$$C_{ex} = \frac{l \times Q \times c_f}{100} + \frac{(C_{SP} + C_J)l}{L_V} + C_E \times k + t_P \times c_m + \frac{C_R + C_{RwT}}{N_L} \tag{8}$$

For an electric vehicle:

$$C_{ex} = \frac{l \times Q_e \times c_e}{100} + \frac{(C_{SP} + C_J)l}{L_V} + C_E \times k + t_P \times c_m + \frac{C_R + C_{RwT}}{N_L}. \tag{9}$$

Final calculations for one laboratory session are 9.21 EUR for an electric and 15.04 EUR for an internal combustion engine.

Results and discussion

To determine the student opinion on electric vehicle use in laboratory sessions instead of internal combustion vehicles, a survey was carried out for the LUA FE and FESD students. The survey included 28 respondents from the FESD and 26 from the FE. These students will be the first to experience electric vehicles in their practical studies.

Because the FE and FESD students have different technical qualification, the survey had slightly different questions for each faculty. The FESD students had 7 questions, but the FE – 8. Five questions are identical, all questions were with variants, only one question for the FE was open type. The analysis of the survey answers follows.

On the first question “Do you think that electric vehicles have future?” 26 FESD or 92.8 % from all respondents and all FE students gave a positive answer.

On the second question “Would you want to use electric vehicles in practical and laboratory sessions?” answer “Yes” was given by 21 FESD or 75 % from all respondents and 20 or 76.9 % respondents from the FE.

24 or 85.7 % FESD students think that electric vehicles are not fully harmless to environment. Also 19 or 73.1 % from the FE students think that electric vehicles have some negative impact on environment.

Only 5 respondents from the FE or 19.2 % from all respondents have ever tried electric vehicles. All 100 % FE students think that a comparison between an analogue electric and internal combustion vehicle would be useful.

14 or 50 % from FESD students think that a comparison between an analogue electric and internal combustion vehicle ecological parameters would be useful. 21 or 75% of FESD students would want

to make comparison between analogue electric and internal combustion vehicle economical parameters.

The student answers about perspective electric vehicles and also use in practical sessions are summarized in Table 1.

By the results given in Table 1, it is established that the answer tendency is similar in both faculties and it is useful to implement electric vehicles in practical and laboratory sessions.

Table 1

Positive answer distribution by faculties

Shortened question	FESD	FE
Electric vehicles have future	92.8 %	100 %
Wants to use electric vehicles in laboratory sessions	75.0 %	76.9 %
Electric vehicles are not fully environment friendly	85.7 %	73.1 %
Wants to make electric and internal combustion vehicle technical characteristics comparison	-	100 %
Wants to make electric and internal combustion vehicle economical comparison	50.0 %	-
Wants to make electric and internal combustion vehicle ecological comparison	75.0 %	-

The biggest advantages for electric vehicles from the student perspective are shown in Figure 1.

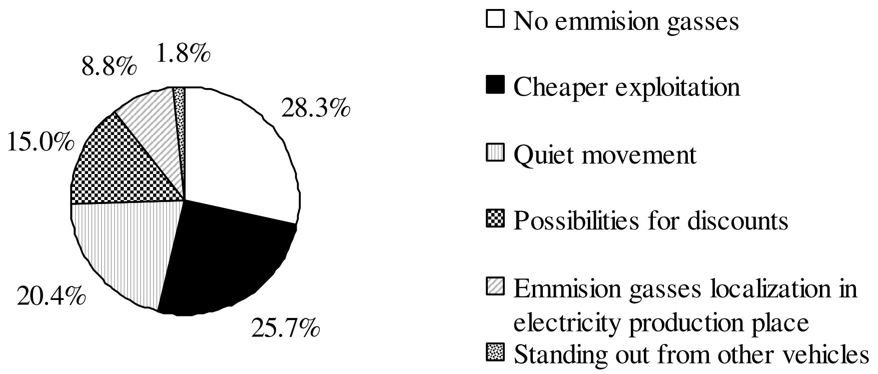

Fig. 1. **FESD and FE student marked advantages for electric vehicle**

The most important disadvantages for electric vehicles from the student perspective are shown in Figure 2.

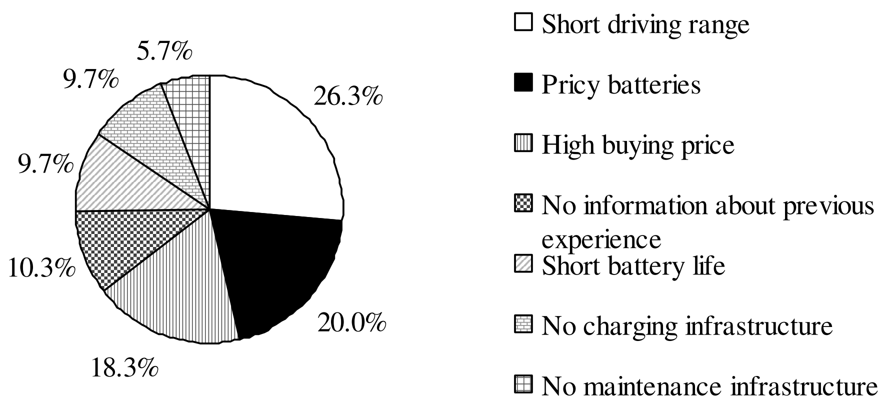

Fig. 2. **FESD and FE student marked disadvantages for electric vehicle**

16 FE students or 61.5 % from the surveyed think that there is not enough experience about electric vehicles for laboratory sessions.

From the student given disadvantages and advantages for electric vehicles, new parameters emerge, that need a special attention in laboratory and practical sessions.

Electric vehicle usage in the "Technical Expert" studies was approbated in 2012 autumn semester. Approbation was done in the study course "Motor Vehicle Theory" for experts for full time and part time third year students. Laboratory session "vehicle on-road experiments" was carried out in the faculty yard, in a 100 m straight part of the road. There are only few students in this course (full time-2 and part time – 6 students) and there are limited possibilities to carry out large scale automobile on-road experiments. That is why an electric scooter with a 500 W engine was used. The scooter is equipped with 3 maximal speed regimes. The following tests were carried out:

- acceleration data gathering with scientific radar "Stalker", chart construction;
- braking data gathering with scientific radar "Stalker", chart construction;
- rolling resistance determination with freerun method;
- air resistance determination with freerun method;
- wheel kinematic radius determination;
- scooter speedometer calibration.

All experiments were done by 2 students, what could not be possible in on-road experiments with an automobile. Good communication between students can be achieved without traditionally used walkie-talkie. Student gained knowledge was evaluated as good.

Conclusions

1. Electric vehicles in laboratory and practical sessions can be used for all four Engineering programs and in one Economics and Social Development study program.
2. Electric vehicle usage in laboratory sessions is very wide – up to 10 different study courses at the Faculty of Engineering study programs and in 2 study courses of the Faculty of Economics and Social Development. It includes both, master and bachelor degrees.
3. Advantages for electric vehicle usage in laboratory sessions are much grater than disadvantages.
4. Doing expenses calculation for one laboratory session, electric vehicle usage can save 38.7 % from all gathered expenses positions.
5. From the poll data about electric vehicle usage, the tendencies are similar for the Faculty of Engineering and the Faculty of Economics and Social Development student answers.
6. Based on most frequently given answers about electric vehicle characteristics, in laboratory sessions vital attention needs to be paid to electric vehicle quiet, no emission and lover cost exploitation analysis.
7. It is useful to make analysis of electric vehicle driving range, battery exploitation and buying cost impact.
8. It is important to include internal combustion engine and electric vehicle different parameter calculation and analysis in laboratory and practical sessions.

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