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Methodology for energy savings assessment, at engine oil change of road vehicles

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Abstract. The presented paper reveals the possibilities of the implementation of a methodology for evaluating energy savings, at changing the engine oil of different road vehicles. The purpose of the developed methodology is to provide an opportunity to evaluate the energy consumption before and after changing the engine oil of the vehicle. The conditions, the practical procedures and the mechanism for evaluating the energy savings after changing engine oils of vehicles are defined. Changing the engine oil of the car covers the replacement of the old oil with a new one within the maximum mileage determined by the manufacturer. The results of the application of the methodology for certain categories of cars allow an easy process of monitoring and verification. And finally, a computational example is considered, proving that the methodology gives correct results for the evaluation of energy savings, after the replacement of the engine oil of the vehicle.

1 Introduction

In recent years, there has been an increase in the requirements towards one of the main goals and policies of the European Union (EU) namely, to reduce CO_2 emissions and other greenhouse gases (GHG). In this concern, the EU is moving towards a carbon-neutral economy by 2050. It also adopts both a 2030 climate and energy framework agreed with EU member states as an economy-wide reduction in greenhouse gases of 40% by 2030. Thus, shares of 32% for renewable energy and 32.5% for improving energy efficiency, are accepted. Subsequently, the European Commission also determined the emissions from transport: a 20% reduction from the levels from 2008 to 2030 and a 60% reduction compared to the levels from 1990 to 2050. Transport was considered as a significant source of emissions in 2016 as well and contributed to 27% of total EU greenhouse gas emissions, with road transport accounting for 72% of them. It follows so far that a reduction in fuel consumption in the transport sector has an impact on the total emissions of the system. In 2017, the European Commission set CO_2 standards from 2021 to 2030 for new cars and vans, and average CO_2 emissions must be 37.5% - 31% lower than in 2021 for 2030. [1-3].

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Technological improvements in lubricants for vehicle engines have had a significant positive effect on the reduction of greenhouse gases and CO_2 emissions in recent years [4-8]. In order to reduce emissions, the Association Technique de l'Industrie Europeenne des Lubrifiants (ATIEL) commissioned Ricardo Energy & Environment to assess historical and future CO_2 savings based on advances in engine lubricant technology through the SULTAN model. Based on the US road vehicle fleet and according to the criteria set in [9], it is estimated that as a result of engine lubrication technologies since 2005 until 2020 respectively, up to 1.2 – 3.9 $MtCO_2e$/y avoided emissions were obtained and will continue to reduce emissions by another 0.9 – 2.7 $MtCO_2e$/y until 2030 [9].

In order to reduce the energy savings, measures applied by EU member states have been generated, according to Article 7 of Directive 2012/27/EU on energy efficiency, related to the methods for calculating energy savings [10]. In 2018, Directive 2012/27/EU was amended by Directive 2018/2002, which sets out a general framework of measures to promote energy efficiency in the US to ensure that this energy efficiency target is met by the most at least 32.5% for 2030 [11-12]. According to the requirements of the directive, Member States need to set their own national energy efficiency targets and increase the growth of cars with e-drives [13].

In March 2021, changes were made to the Law on Energy Efficiency, which regulated the way in which the national goal for energy efficiency in Bulgaria is determined until 2030. Both obligations for energy savings and alternative measures were introduced, which ensure the achievement of the target for energy savings in final energy consumption for the period from the beginning of January 2021 to the end of December 2030 [14].

According to the authors, reference [12] includes general requirements and key principles that should be taken into account in the methodologies for calculating energy savings in EU member states.

The main goal of the presented study is to develop a methodology for evaluating the energy savings when changing the engine oil of road vehicles in Bulgaria, in accordance with the legislation of the country and the EU. The methodology defines the conditions, the practical procedures and the mechanism for evaluating the energy savings after changing engine oils of vehicles. The results of the research will be useful in finding solutions to reduce greenhouse gas emissions in line with EU climate change legislation.

2 Materials and Methods

2.1 General conditions in the development of the methodology

Considering the presented requirements of the World, European and Bulgarian legislation for the reduction of greenhouse gases and CO_2 emissions, a methodology has been developed for evaluating the energy savings when changing the engine oil of vehicles. In order the calculation procedure of the methodology to be correct, it must meet the following requirements:

The methodology defines the conditions, practical procedures and the mechanism for evaluating energy savings after changing engine oils of vehicles;

Changing the engine oil of the car covers the replacement of the old oil with a new one within the maximum mileage determined by the manufacturer;

The purpose of the methodology is to provide an opportunity to evaluate energy consumption before and after changing the engine oil of the vehicle;

The methodology defines the main steps and principles of the procedure for proving the energy savings achieved by a third party;

The results from the methodology application are proven by the New General Requirements Document for Light-Duty and Heavy-Duty ACEA Oil Sequences. This revision includes the references [15] and [16] for certain categories of cars. They enable the implementation of a simple monitoring and verification process.

The methodology allows for the possibility of estimating the energy savings after the replacement of the vehicle's engine oil to be calculated numerically.

2.2 Application characteristics of the energy service

Scope of the energy service offered

The methodology is only applicable to vehicles of categories M1, M2 and N1, which were first registered after 2007, i.e. Euro 4, Euro 5 and Euro 6.

The fuel economy is according to item 2.5 (New General Requirements Document for Light-Duty and Heavy-Duty ACEA Oil Sequences. This revision includes the references [15] and [16] and applies to SAE XW-30 oils; XW-20, or directly quoted ASEAN class and having a minimum fuel economy (petrol or diesel) greater than 2.5%.

Application sector

The methodology is applicable to the assessment of saved energy after changing the engine oil of a group of cars of a corresponding category in the field of transport.

2.3 Characteristics of the proposed methodology

The methodology is based on the application of calculation procedures that are also applied in other countries.

The calculation procedure includes several basic steps applied after processing analytical information on the number of vehicles of categories M1, M2 and N1, which are first registered after 2007, i.e. Euro 4, Euro 5 and Euro 6, and use engine oils SAE XW-30; XW-20.

The lubricating properties of energy-efficient oils and their role in maintaining better operating parameters of engines are taken into consideration. The calculation procedure is as follows:

Calculation of supplied energy with fuels (gasoline, diesel, propane-butane, methane);

Calculation of energy consumption after changing the engine oil of the road vehicle (RV);

Calculation of the amounts of final energy saved;

Calculation of the amounts of CO_2 emissions saved by the end user.

2.4 Additional information for methodology application

Terminology

T- period of action (technical life) – is the kilometers traveled after the implementation of the measure, during which it is assumed that the engine works economically, according to the action for which they were designed and lead to measurable results on energy consumption.

f_r – coefficient of reduced fuel consumption after changing the engine oil, %

The coefficient accounting for the reduced fuel consumption of the car after the engine oil change is found in accordance with item 2.5. (New General Requirements Document for Light-Duty and Heavy-Duty ACEA Oil Sequences. This revision includes the references [14] and [15] applies to SAE XW-30 oils; XW-20 or directly quoted ASEA class and having a minimum fuel economy (petrol or diesel) greater than 2.5%.

Coefficient of reduced fuel consumption after changing the engine oil is 0.975, f_i – Emission factor (t_{CO_2}/kWh) (Calculated according to Table 1 [17]);

Table 1. Reference values of the coefficient of ecological equivalent of energy/fuel.

Type of energy/fuel	f_i tCO_2/GWh
Industrial gas oil, diesel	267
Propane-butane	227
Methane	202
Gasoline	263

e_p – coefficient accounting for the losses of extraction/production and transmission of energy and energy resources ((Found according to Table 2 [17]);

Table 2. Reference values of the coefficient accounting for losses for extraction/production and transmission of energy, including fuels.

Type of energy/fuel	e_p
Industrial gas oil, diesel	1.1
Propane-butane	1.1
Methane	1.1
Gasoline	1.1

ρ_{fuel} – fuel density, (kg/m^3) (Calculated according to Table 3 [18]);

LHV_{fuel} - lower heating value of combustion of fuel, ($kWh/$kg) (Calculated according to 3 [18]).

Table 3. Reference values of fuel density and lower heating value of combustion of fuel (LHV), for the different types of fuels.

Type of fuel [-]	Density kg/l	LHV of combustion kWh/kg
Diesel	0.832	11.860
Gasoline	0.745	12.209
Propane-butane (LPG)	0.538	12.791
Methane (CNG)	0.554	13.100

D – average mileage of a vehicle of the respective category, (km$/y$) .

N – number of registered vehicles of the respective category (Euro 4, Euro 5 and Euro 6) with engine oil changed SAE XW-30; XW-20;

D_a – average annual mileage of the vehicles of the respective category, (km$/y$)

F_B – average fuel consumption of all vehicles of the respective category (i=1,2,3), l/100 km;

Q_B – annual fuel consumption per vehicle category before engine oil change, (l$/y$);

FE_B – energy delivered with the fuel for the respective vehicle category before the engine oil change, (MWh/y);

Q_A – annual fuel consumption for vehicle category after engine oil change, (l$/y$);

F_A– average fuel consumption of all vehicles of the respective category after changing the engine oil (i=1,2,3), l/100 km, where:

FE_A– delivered energy with the fuel for the respective category of vehicles after changing the engine oil, (MWh$/y$);

PES – primary energy saved, MWh/y;

2.5 Calculation of energy savings according to the methodology

The methodology takes into account the difference between the energy used before and after the introduction of new energy-efficient motor oils.

2.5.1 Calculation of the energy saved and reduced carbon emissions when changing the engine oil of a car

Energy savings

1. **Average annual mileage for all cars:**

$$D_a = N * D\ (km/y), \tag{1}$$

where:
D_a – average annual mileage of the vehicles of the respective category, (km/y)
N – number of registered vehicles of the respective category (Euro 4, Euro 5 and Euro 6) with engine oil changed SAE XW-30; XW-20;
D – average mileage of a vehicle of the respective category, (km/y) .

2. **Annual fuel consumption for the relevant vehicle category before changing the engine oil:**

$$Q_B = F_B * D_\mathrm{a}\ (l/y), \tag{2}$$

where:
Q_B – annual fuel consumption per vehicle category before engine oil change, (l/y);
F_B – average fuel consumption of all vehicles of the respective category (i=1,2,3), l/100 km;
D_a – average annual mileage of the vehicles of the respective category, (km/y)

3. **Delivered energy with fuel before engine oil change**

$$FE_B = Q_B * \rho_{fuel} . LHV_{fuel}\ (\mathrm{MWh}/y), \tag{3}$$

where:
$F\mathrm{E}_B$ – energy delivered with the fuel for the respective vehicle category before the engine oil change, (MWh/y);
Q_B – annual fuel consumption per vehicle category before engine oil change, (l/y);
ρ_{fuel} – fuel density, (kg/m^3) (Calculated according to Table 3 [18]);
LHV_{fuel} - lower heating value of combustion of fuel, (kWh/kg) (Calculated according to Table 3 [18]).

4. **Annual fuel consumption for the relevant category of vehicles after changing the engine oil:**

$$Q_\mathrm{A} = F_\mathrm{A} * D_\mathrm{a}\ (l/y), \tag{4}$$

where:
Q_A – annual fuel consumption for vehicle category after engine oil change, (l/y);
F_A- average fuel consumption of all vehicles of the respective category after changing the engine oil (i=1,2,3), l/100 km, where:

$$F_A = F_B - F_B * f_r \ (l/y), \tag{5}$$

f_r – coefficient of reduced fuel consumption after changing the engine oil, % (Table 4)
D_a – average annual mileage of the vehicles of the respective category, (km/y)

5. Energy delivered by fuel before engine oil change

$$FE_A = Q_A * \rho_{fuel}.LHV_{fuel} \ (MWh/y), \tag{6}$$

where:
FE_A- Delivered energy with the fuel for the respective category of vehicles after changing the engine oil, (MWh/y);
Q_A – annual fuel consumption for vehicle category after engine oil change, (l/y);
ρ_{fuel} – fuel density, (kg/m^3) (Calculated according to Table 3 [18]);
LHV_{fuel} - lower heating value of combustion of fuel, (kWh/kg) (Calculated according to Table 3 [18]).

6. Final energy saved

$$FES = FE_B - FE_A \ (MWh/y), \tag{7}$$

where:
FES – final energy saved, MWh/y;
FE_B – energy delivered with the fuel for the respective vehicle category before the engine oil change, (MWh/y);
FE_A – Delivered energy with the fuel for the respective category of vehicles after changing the engine oil, (MWh/y);

7. Savings of primary energy

$$PES = (FE_B - FE_A).e_p \ (MWh/y), \tag{8}$$

where:
PES – primary energy saved, MWh/y;
FE_B – energy delivered with the fuel for the respective vehicle category before the engine oil change, (MWh/y);
FE_A – Delivered energy with the fuel for the respective category of vehicles after changing the engine oil, (MWh/y);
e_p – coefficient accounting for the losses of extraction/production and transmission of energy and energy resources ((Found according to Table 2 [17])

Carbon dioxide emissions saved

1. CO_2 savings

$$CO_2 = FES.f_i(\frac{t_{CO_2}}{\text{г}}), \tag{9}$$

where:
FES final energy saved, MWh/y;
f_i – Emission factor (t_{CO_2}/kWh) (Calculated according to Table 1 [17]).

3 Results and discussion

Based on the studies performed in the field of reducing greenhouse gases and CO_2 emissions and the developed methodology for evaluating the energy savings when changing the engine oil of vehicles, a calculation example is presented in Table 5, Table 6 and Table 7. The maximum mileage for changing the oil is 10,000 km. In Table 4 are presented the four categories of road vehicles, which were considered in the presented study:

Table 4. Vehicle categories.

№	Category	Type of vehicle	Weight	Number of passengers
1	M1.1	Private	3.5 tons	Up to 6
2	M1.2	Company	3.5 tons	Up to 6
3	M2	Cars up to 3.5 tons	3.5 tons	6-8
4	N1	Light trucks up to 3.5 tons	3.5 tons	-

Table 5. Calculation example – part 1.

№	Type of road vehicle	Type of fuel	Vehicles with changed oil, only EURO 4.5.6	Average fuel consumption before oil change	Average mileage of a car in category	Average mileage of a car for oil change	Average annual mileage for all cars
	M type	Fuel (-)	N number	F_B l/100 km	L km/y	D km/y	D_a km/y
1	M1.1	gasoline	665 332	7.94	11 067	11 067	7 252 559 224
2	M1.2	gasoline	62 130	8.37	20 399	20 399	1 267 389 870
3	M2	gasoline	794	11.10	12 308	12 308	9 772 332
4	N1	gasoline	304	10.51	20 278	20 278	6 164 389

Table 6. Calculation example – part 2.

№	Annual fuel consumption per category before oil change	Energy delivered with the fuel	Average fuel consumption of a car of a category after an oil change	Annual fuel consumption after oil change	Energy delivered with the fuel after an oil change
	Q_B l/y	FE_B MWh/y	F_A l/100 km	Q_A l/y	FE_A MWh/y
1	575 853 204	5 237 791	7.74	561 456 874	5 106 846
2	106 080 532	964 877	8.16	103 428 519	940 755
3	1 085 172	9 870	10.83	1 058 043	9 624
4	647 991	5 894	10.25	631 791	5 747
Total	**683 666 899**	**6 218 432**		**666 575 226**	**6 062 972**

Table 7. Calculation example – part 3.

№	Net final energy	Final energy saved	Primary energy saved	Emissions saved
	FE_A MWh/y	FES MWh/y	PES MWh/y	CO_2 t/y
1	5 106 846	130 945	144 039	34 438
2	940 755	24 122	26 534	6 344

3	9 624	247	271	65
4	5 747	147	162	39
Total	**6 062 972**	**155 461**	**171 007**	**40 886**

After applying the methodology for evaluating the energy savings at changing the engine oil of vehicles in the calculation example, the following results were obtained: for the annual amount of final energy saved (FEStot) – 155 461 MWh/y; for the annual amount of saved primary energy (PEStot) – 171 007 MWh/y and for the amount of saved carbon emissions (CO2) – 40 866 t. The results of applying the methodology are applicable only to certain categories of cars and practice shows that they enable an easy process of monitoring and verification.

4 Conclusions

The developed methodology for evaluating the energy savings, when changing the engine oil of vehicles, makes it possible to calculate the energy consumption of the vehicle after the oil change. Changing the engine oil of the car covers the replacement of the old oil with a new one, within the maximum mileage determined by the manufacturer. The methodology is applicable only to vehicles of categories M1, M2 and N1, which are first registered after 2007, i.e. Euro 4, Euro 5 and Euro 6. In addition, the application defines the main steps and principles of the procedure for third-party proof of energy savings achieved. As a result of the considered calculation example, the following results were obtained: for the annual amount of saved final energy (FEStot) – 155 461 MWh/y; for the annual amount of saved primary energy (PEStot) – 171 007 MWh/y and for the amount of saved carbon dioxide emissions (CO2) – 40 866 t, which confirm the use of the methodology.

It can be concluded that the methodology allows the possibility of estimating the energy savings after the replacement of the vehicle's engine oil, to be calculated by using the methodology. This would help reduce greenhouse gas emissions and CO_2 emissions worldwide.

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