ANALELE UNIVERSITĂȚII
"EFTIMIE MURGU" REȘIȚA
ANUL XVIII, NR. 1, 2011, ISSN 1453 - 7397

Jevto Lučić, Nenad Zrnić

Alternative Drive Systems as a Part of a GHG Emission Reduction

Air pollution as a consequence of a modern way of life contaminates the natural environment and brings us the global warming which poses a clear and present danger to civilization. The main causes of global warming are greenhouse gasses, which arise of reliance on fossil fuels, deforestation, agriculture, industrial processes and transport. The transport itself makes 14% of the main causes of greenhouse gasses. Its dependence on fossil fuels, together with the decrease of a world fossil fuels reserves, force us to look for alternative fuels and to develop alternative drive systems, which can stabilize and reduce the greenhouse effect, and at the same time offer us new technologies, independent on a fossil fuels. This paper will try to present potential solutions for this problem, and to show the development of alternative drive systems.

Keywords*: greenhouse gasses, vehicle emission, alternative drive systems*

1. The Greenhouse Effect

There are a lot of side effects that civilization, with its progress, brings to us. Growing population, reliance on fossil fuels, agriculture, forestry, and transport increment brought us a significant increase of pollutant emissions which is emitted in atmosphere. The proportion of the emission caused by human intervention, together with the natural sources makes greenhouse effect which is responsible for global warming. The proportion of gases emitted in air from purely human-caused sources is known as the anthropogenic greenhouse effect. The main causes of greenhouse gases are shown on Figure 1 [1].

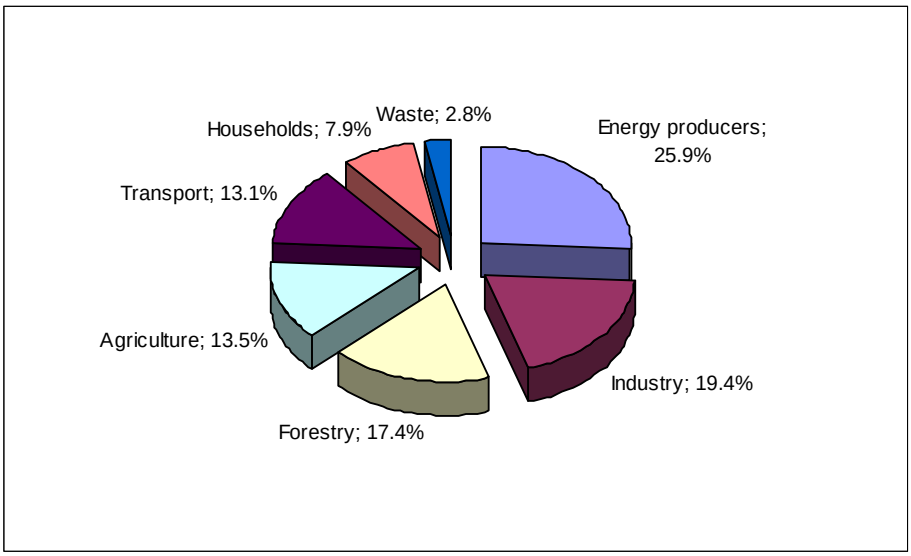

Figure 1. The main causes of greenhouse gases [1]

Besides direct emissions which transport generates with fuel combustion, there are significant indirect emissions generated as a result of transport activities, such as production of the vehicles which requires energy, in particular for primary products (e.g. steel, aluminum and plastic), the use of transport infrastructure like roads, rail-lines, harbor facilities, bridges, car parks, tunnels or filling stations which requires energy for construction work, maintenance and production of materials (e.g. asphalt, concrete and steel) [2]. Also, production of the vehicles requires energy, in particular for primary products (e.g. steel, aluminum and plastic). Besides from these material related emissions, production of fuels generates emissions from extraction, refining and transportation, which has to be calculated into indirect emissions, too.

To reduce and stabilize this effect, United Nations Framework Convention on Climate Change (UNFCCC) adopted Kyoto Protocol on 11 December 1997. This protocol set out a binding agreement to reduce greenhouse emissions in industrialized nations. Under this protocol countries that signed it committed themselves that will reduce greenhouse gases emission at a level that would prevent dangerous anthropogenic interference with the climate system. As of July 2010, 191 states have signed and ratified the protocol (Serbia, as a UNFCCC member, ratified the protocol on 24 September 2007) [3].

The gases controlled under the Kyoto protocol include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6) and two groups of gases- fluorohydrocarbons and perfluorocarbons (HFCs), and their effect is shown on Figure 2 [2].

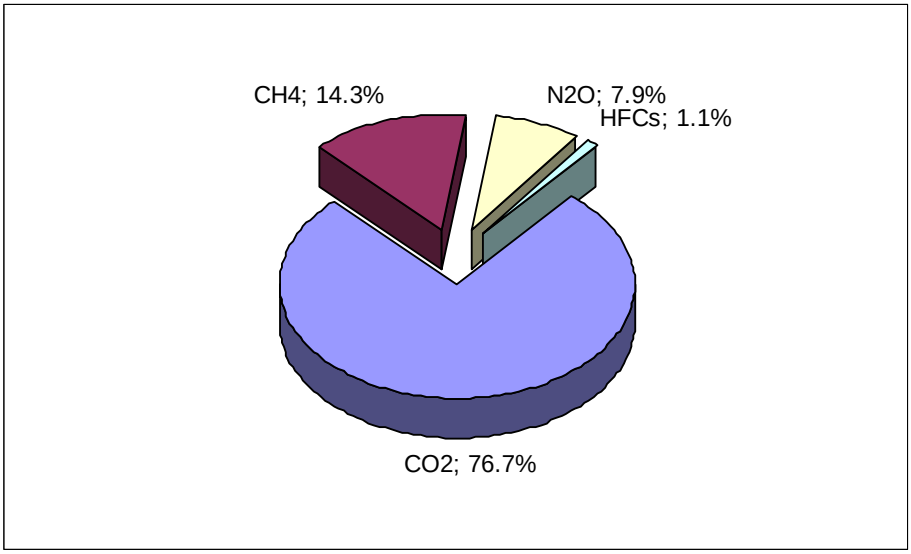

Figure 2. Anthropogenic greenhouse gas emissions in 2004 [2]

The largest source of greenhouse gas emissions is Carbon dioxide (CO_2), which accounted for 76.7% of the anthropogenic greenhouse effect in 2004. Due to that, CO_2 is used as the reference for measuring the amount of greenhouse gases. Methane (CH_4) is the main constituent of natural gas and biogas and is released mainly in agriculture as a result of rearing cattle, or generated by the fermentation of organic matter (manure, wastewater sludge, municipal solid waste or any other biodegradable feedstock). It accounts for approximately 14.3% of the anthropogenic greenhouse effect, but, calculated on a time period of 100 years, has the greenhouse potential which is 25 times higher that carbon dioxide. Nitrous oxide (N_2O) accounts for approximately 7.9% of the anthropogenic greenhouse effect, but calculated on a time period of 100 years has 298 times higher greenhouse potential than carbon dioxide. Fluorohydrocarbons (HFCs) accounts for approximately 1.1% of the anthropogenic greenhouse effect, and their greenhouse potential is between 1,430 to 14,800 times higher (depending of a type of fluorohydrocarbons) than carbon dioxide (calculated or a time period of 100 years). Sulphur hexafluoride (SF_6) is the most potent greenhouse gas, with its potential which is 22,800 times higher that carbon dioxide (calculated or a time period of 100 years), but due to its low concentration in the atmosphere, it has a minor affect on global warming [4].

2. European legislation for reduction of motor vehicles pollution

On 20 March 1970, European Economic Community (European Union at present), in order to reduce air pollution by motor vehicles, introduced Council Directive 70/220/EEC with measures to be taken against air pollution by gases from internal combustion engines of motor vehicles. European Commission, since then, developed more than 24 Directives and amendments to stepwise tighten the limit values [5]. From beginning of 1990, European Commission introduced EURO norms which strengthen maximum permissive values of carbon monoxide, particulates, nitrogen oxide and hydrocarbons which can be emitted by motor vehicles. More stringent limits are introduced on 13 October 1998 with Directive 98/69/EC and defined EURO 3 for vehicles which became mandatory in 2001. Nowadays Euro 5 emission norm is mandatory in most markets of Europe, not only in European Union, and the inbound EURO 6 will be mandatory in 2014. By their implementation, emissions of air pollutant gases from motor vehicles are decreased significantly (from 69.39% for CO, to 95.56% for NOx) [5], which are shown on Figure 3 and Table 1.

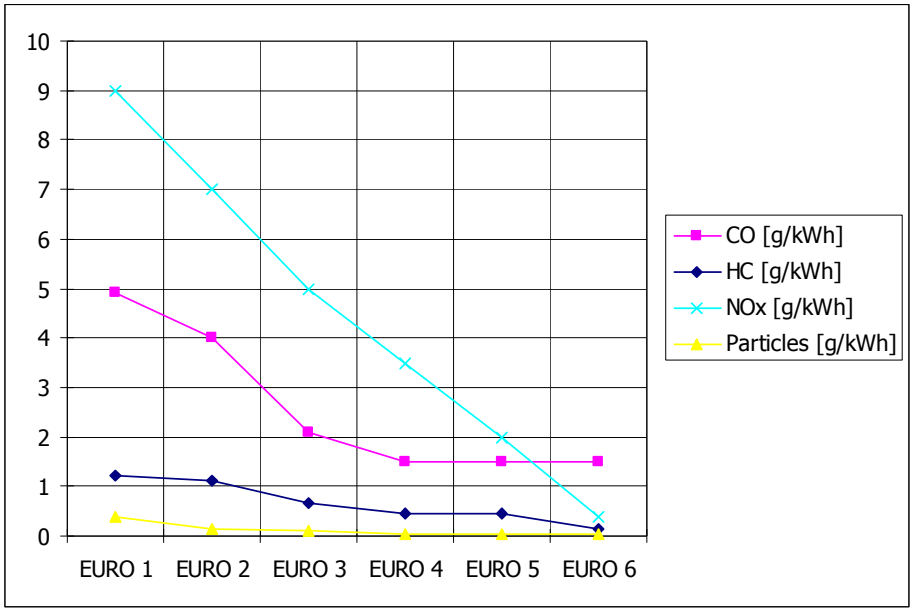

Figure 3. Permitted values of emissions in EURO norms [5]

Table 1. Permitted values of emissions in EURO norms [5]

Maximum permissive values	CO [g/kWh]	HC [g/kWh]	NOx [g/kWh]	Particles [g/kWh]
EURO 1	4.9	1.23	9	0.4
EURO 2	4	1.1	7	0.15
EURO 3	2.1	0.66	5.0	0.1
EURO 4	1.5	0.46	3.5	0.02
EURO 5	1.5	0.46	2	0.02
EURO 6	1.5	0.13	0.4	0.02

Of course, not all these emissions norms are set out to reduce all greenhouse gases, in particular CO_2. However, since CO_2 emissions directly correlate to fuel consumption, by these measures fuel consumption has been reduced, in a field of heavy trucks even for 30%, which substantially reduced CO_2 emission, too.

3. Alternative fuels

In a search for ways of reducing the dependence on petroleum and to reduce pollutant emissions, alternative fuels are becoming increasingly important. Their main problem is to meet a range of different conditions- they should be usable in conventional combustion engines with a minimal changes to vehicle technology and to be manufactured from renewable energy sources, and their production must not lead to loss of arable land for food production and to deforestation of the rain forests [6]. Only fuels that sustainably reduce CO_2 emissions can be considered as alternative fuels.

Right now, there are wide variety of renewable energy sources that can be used as alternative, such as biodiesel, bioethanol, compressed biogas, biomass to liquid (BTL), vegetable oil, hydrogenated vegetable oil (HVO), hydrogen. They can be produced from vegetable oil and animal fats (biodiesel), generating by fermenting parts of plants containing sugars or starch (bioethanol), produced from waste or unused parts of plants or cultivated energy crops through fermentation in a biogas plant (compressed biogas), or, as for BTL diesel, the entire harvested biomass can be used for production. One of the alternative fuels with very high CO_2 reduction potential is hydrogen, which can be generated from water using electrolysis and can be used in conventional engines as alternative fuel, or be used in fuel cell. The main problem is the quantity and source of energy that has to be used for production of alternative fuels, and their production price.

Besides renewable energy sources, there are a list of fossil fuels that can be used as alternative to conventional fuels, such as liquefied petroleum gas (LPG) – a mix of propane and butane, compressed natural gas (CNG) - methane, liquefied natural gas (LNG) – CNG cooled on -164°C, which compared to gasoline emits less CO_2 emissions [7], and others, such as dimethyl ether (DME) which is mainly used

as an admixture for LPG or conventional diesel fuel, dual fuels, gas to liquid (GTL), coal to liquid (CTL), methanol, etc.

4. Alternative drive systems

Alternative drive systems have a higher potential to reduce problems with air pollution and GHG emissions, and problems with the decreasing fossil fuel reserves. A whole range of different technical solutions are developing, among them, four alternative drive system concepts are the most promising. They are gas engine, electric, fuel cell and hybrid drive systems. Electric vehicles offer true zero carbon and air pollution emissions on the road. Battery- and fuel-cell electric vehicles are the most prominent alternatives to the internal combustion engine [2], while gas engine with its low emission and price is a good alternative for conventional fuels in present combustion engines. Despite a wide range of concepts that are developing, it is still not clear which concept will prevail.

Gas engine is a conventional combustion engine that uses natural gas or biogas instead of liquid fuels. Gas engines offer low emission combustion [7] and a good CO_2 LCA. Since there are no developed gas filling station network and their low autonomy, gas- powered vehicles are using at present mainly for municipal applications and in urban areas.

Fuel cell vehicles, powered by hydrogen produce the electricity for propulsion by electrochemical reactions of hydrogen with oxygen. They are more efficient than conventional internal combustion engine vehicles and produce no harmful exhaust emission, since their only emission is water vapour. Fuel cell vehicles use electricity produced by electrochemical reactions to power motors located near the vehicle's wheels, like electric vehicles, but the difference is that they produce their primary electricity using a fuel cell. The fuel cell can be fueled with hydrogen gas stored directly on the vehicle or extracted from a secondary fuel- methanol, ethanol, or natural gas, by an onboard device called a reformer. Fuel cell vehicles fueled with pure hydrogen emit no pollutants, only water and heat.

Vehicles that use secondary fuels and a reformer produce only small amounts of air pollutants. Fuel cell vehicles can be equipped with other advanced technologies to increase efficiency, such as regenerative braking systems, which capture the energy lost during braking and store it in a large battery. Main problem of fuel cell are high production costs and complex hydrogen production.

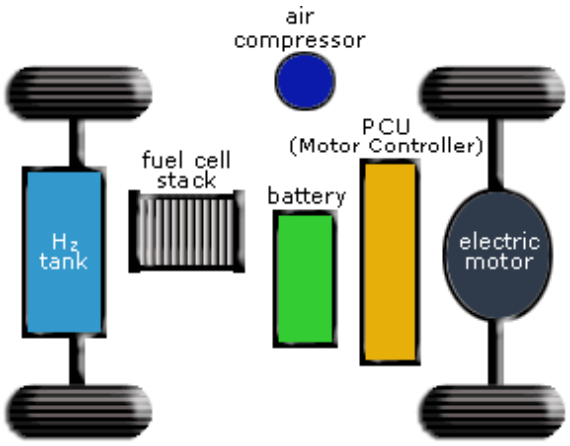

Figure 4. Schematic of a fuel cell vehicle

Electric driven vehicles powered with electric motors are more efficient that conventional combustion engines. Their electric motor can be used also as an auxiliary brake and recover energy. The only emissions that can be attributed to electricity are those generated in the production process at the power plant. If electricity is generated in solar or wind power plants, the usage of electric drive can be entirely CO_2 free. Electric vehicles produce zero local exhaust emissions and low noise. Electric vehicles carry their energy along on-board in chemical form in batteries. One of the major problems they are facing is low autonomy due to battery capacity, battery weight and battery life. Nowadays nickel metal hydride (NiMH) batteries in a power-optimized version are mainly used (they are now fitted hybrid vehicles such as the Toyota Prius) have the disadvantage of low energy density and high additional weight, which reduce the driving range. The better potential for higher energy has high-energy lithium- Ion batteries, which are seen as a battery solution for the future. They are developing in several versions, and the most interesting for traction purposes are the lithium-ion and the lithium–polymer batteries. Although the lithium batteries are now on the brink of series production, further optimization such as production cost, system safety and stability and production cost is still being performed. Because of that, the lithium systems cannot be considered as a commercially available product yet. [9]

Electricity can be used to power electric and hybrid electric vehicles directly from the power grid. Vehicles that run on electricity are suitable for short-range driving, while hybrid vehicles could have better driving range. Hybrid technology and hybrid vehicles are available since the 1990ies. In 2006 approximately 400,000 hybrid cars were sold which is less than 1% of the world car production [2]. In the USA and Japan the large numbers of buses and trucks with hybrid technology from the Daimler brands Orion, Freightliner and Mitsubishi Fuso are in fleet operation. In

2007 were around 1500 Orion hybrid buses, more than 100 Freightliner vehicles and 200 light trucks and buses by Fuso in customer operation. In Germany, France, Great Britain and the Czech Republic since 2008 hybrid trucks and busses from Daimler brands are into pilot-operation [10]. For the future, an increasing number of hybrid models are expected. Hybrid drives consist of at least two different energy converters and two energy storage components. At the present, there are several different hybrid architectures in combination with conventional combustion engines and levels of hybridization. Two most promising designs are hybrid vehicles with parallel and hybrid vehicles with series configuration. Hybrid vehicles with parallel configuration have a direct mechanical connection between the hybrid power unit and the wheels, as in a conventional vehicle, but also have an electric motor that drives the wheels. Because of that, they can use the power from conventional combustion engine for highway driving, end power from both combustion engine and electric motor for accelerating. The benefits are that smaller engine can provide more efficient operation and therefore better fuel economy and they do not need separate generator because the engine itself regenerates the batteries. Because of that, hybrid vehicles with parallel configuration are the good solution for trucks [10].

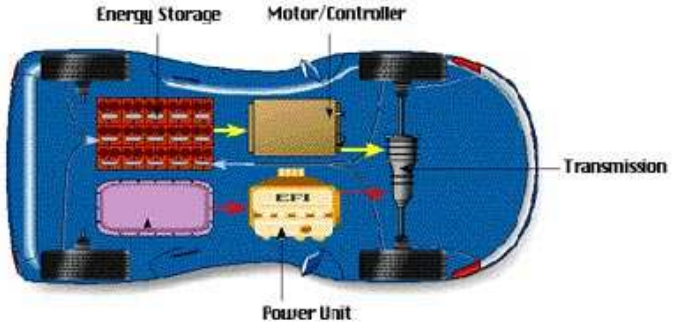

Figure 5. A hybrid electric vehicle (HEV) with a parallel configuration

Hybrid vehicles with series configuration use the fuel cell with generator or the heat of the engine to produce the electricity for the batteries and electric motor. They have no mechanical connections between the hybrid power unit and the wheels. Because of that, all motive power has been transferred from chemical energy to mechanical energy to electrical energy, and back to mechanical energy to drive the wheels. The benefits of this design are that the engine newer idles, which reduces vehicle emissions, and it can continuously operate in most efficient region, which make them good solution for busses [10]. The main problem is that they need larger and heavier batteries, and its inefficiency in converting the energy from chemical to mechanical to electrical, and back to mechanical.

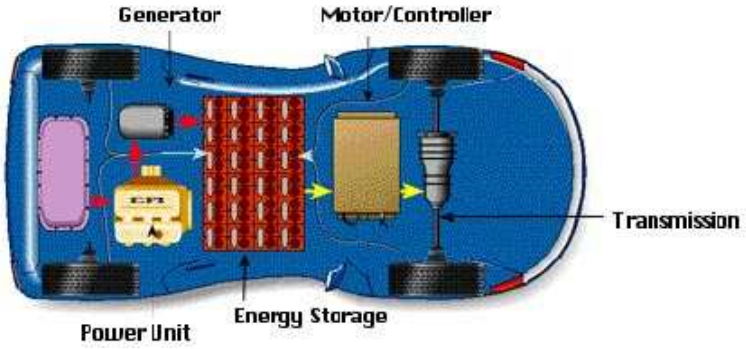

Figure 6. A hybrid electric vehicle (HEV) with a series configuration

5. Conclusion

Two main goals we have are to fight with the global warming through reduction of vehicle emission and to decrease the dependence on fossil fuels in order to preserve fossil sources of energy. By obeying the European legislation for reduction of motor vehicles pollution, emissions of particulates and nitrogen oxides have decreased by more than 90% on average since 1990ies and in a same time decreased the average fuel consumption for 30%. Using alternative fuels will help to preserve fossil sources of energy and in a same time will enable use of conventional drive systems. Their main problem is how to reduce the energy which has to be spent to produce alternative fuels, and their production cost. Alternative drive systems have a further potential to reduce problems with air pollution and GHG emissions, and problems with the decreasing fossil fuel reserves. Gas engines are near to zero emission, and trucks and buses equipped with hybrid drives also produce fewer pollutants and less CO2 because of their decreased fuel consumption. The main problem of alterative drive systems nowadays is that hybrid vehicles cost one-third more than today's diesel vehicles, and fuel-cell drive is still not fully developed technology, with inefficient design, high cost, while the electric vehicles still have the problem with low energy density and high additional weight of batteries, which reduce the driving range [8]. For sure, the economic aspects will play a crucial role in the acceptance of alternative fuels and alternative drive systems by the market and it is still not clear which concept will prevail in future. The environmental protection will only be effective in the long term, if it also provides economic benefits to customers.

References

[1] Rogner H.-H., Zhou D., Bradley R., Crabbé P., Edenhofer O., Hare B. Australia), Kuijpers L., Yamaguchi M. , *2007: Introduction. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)]*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007

[2] Uherek E., Halenka T., Borken-Kleefeld J., Balkanski Y., Berntsen T., Borrego C., Gauss M., Hoor P., Juda-Rezler K., Lelieveld J., Melas D., Rypdal K., Schmid S., *Transport impacts on atmosphere and climate: Land transport,* Atmospheric Environment 44, 2010, 4772-4816

[3] www.wikipedia.org, accessed on 03.03.2011

[4] Fuglesvedt J. S., Shine K.P., Berntsen T., Cook J., *Transport impacts on atmosphere and climate: Metrics*, Atmospheric Environment 44, 2010, pp. 4648–4677

[5] ***** *Regulation (EC) No 715/2007 Of The European Parliament*, Official Journal of the European Union, 2007

[6] Goncalves G., Farias T., *Consumption and pollutant emissions of light duty vehicles using alternative fuels,* 12th WCTR, July 11-15, 2010 Lisbon, Portugal

[7] *** *SHV GAS. Why LPG?* – Brochure, from http://whylpg.shvgas.com/, accessed on 10.07.2011.

[8] Burnewicz J., Borkowski P*., Innovative Perspective of Transport and Logistics,* 12th WCTR, July 11-15, 2010 Lisbon, Portugal

[9] Van Dan Bossche, P, Vergels, F, *SUBAT: An assessment of sustainable battery technology,* Journal of Power Sources, Vol.162, Issue 2, pp. 913-919, 2006.

[10] ***** *Shaping Future Transportation,* Daimler Communications, Daimler AG, November 2007, Germany

Addresses:

- Dipl. Eng. Jevto Lucic, Mercedes Benz Srbija i Crna Gora doo, Omladinskih brigada 33, 11070 Belgrade, Serbia, jevto.lucic@gmail.com
- Prof. Dr. Eng. Nenad Zrnic, Department for Material Handling, Constructions and Logistics, Faculty for Mechanical Engineering, University of Belgrade, Kraljice Marije 16, 11000, Belgrade, Serbia, nzrnic@mas.bg.ac.rs