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AUTOMOTIVE ENERGY POLICIES AND THE FLEXIBLE FUEL VEHICLE USAGE

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Abstract.*Since de creation and spread of the automobile worldwide, started the dependence of gasoline usage in modern society as a main fuel, this great need generated and crisis after another in its raw material, the crude oil, as consequence rasing financial problems in several countries and the continuous rising in its prices. Beyond this, the pollution effects by the burn of fossil fuels came to the surface, and for all of this motivated the main countries to organize and create alternatives to the gasoline usage. Than this paper analyses the automotive energy policies in the main technology developers and the use of ethanol as a fuel in Brazilian case of flexible fuels vehicles, as an option of alternative fuel usage and energy matrix development. However it is necessary looking forward to the implications of this technological step, because with the launch of new automotive policies in Brazil, it is necessary to pay attention to national automotive energy efficiency and the disadvantages in the use of flexible fuel vehicles on gasoline.*

Keywords:*Automotive Energy Policies, Ethanol, Internal Combustion Engine, Automotive Energy Efficiency.*

1. INTRODUCTION

The alternative Internal Combustion Engines (ICE) was invented by Jean Joseph Etienne Lenoir in 1858 and since then, the automotive industry with Henry Ford in 1903 among others, contributed to the growth of the quantity of vehicles running on the streets around the world (Fernandes, 2002). In Popular Science(1929), said that in the 1929 before the north-American great depression, the world had 32.028.500 automobiles in use and from these more than 90% of them were produced in USA, the Fig. 1 shows the growth of vehicles number.

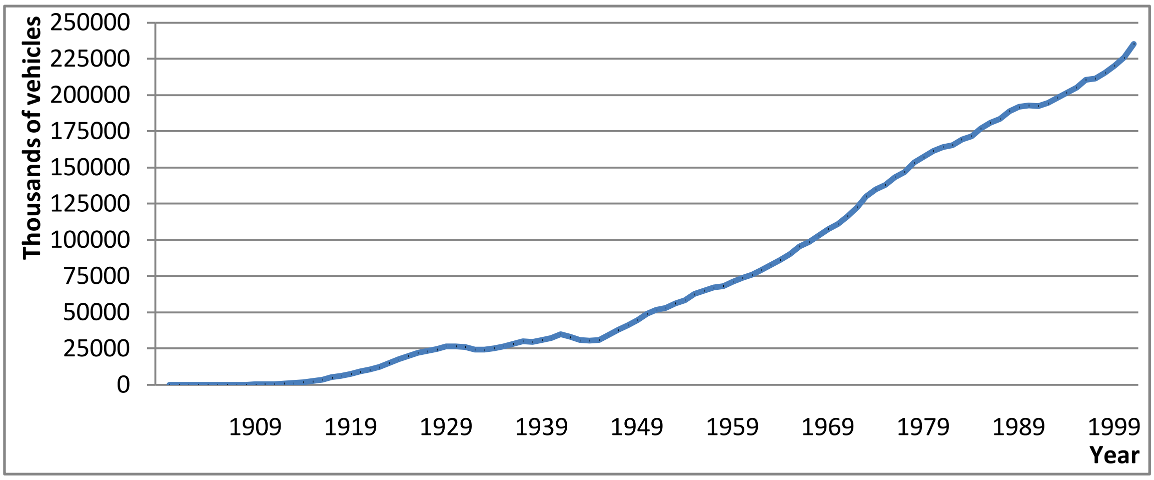

Figure 1.Evolution of vehicle registration in the USA. Source: US Census Bureau (2012).

This rampage in vehicle number generated a great demand on gasoline use and production. This situation endures nowadays because of the oil crisis seen in 1973 and 1979 mainly (as can be seen in Fig. 2 reflecting in the price of gasoline), and these problems in the use of oil derivatives and the suppliers that constantly generate political problems (Pereira, 2008 and Bosco, 2003).

The dependence on oil, as shown in Fig. 3, oil is the most used in the world, creating a worldwide need in the main countries of automotive technology development, for strong measures composing the trends of automotive energy policies based on energy security and sustainable development of technologies (IEA, 2011).

This paper intend to observe the main automotive energy policies (USA, Japan and Europe Union), analyze the usage of flexible fuel vehicles in the Brazil scenario and propose improvements in a trend of better energy efficiency vehicles for specific ethanol powered engines (InovaEnergia, 2013).

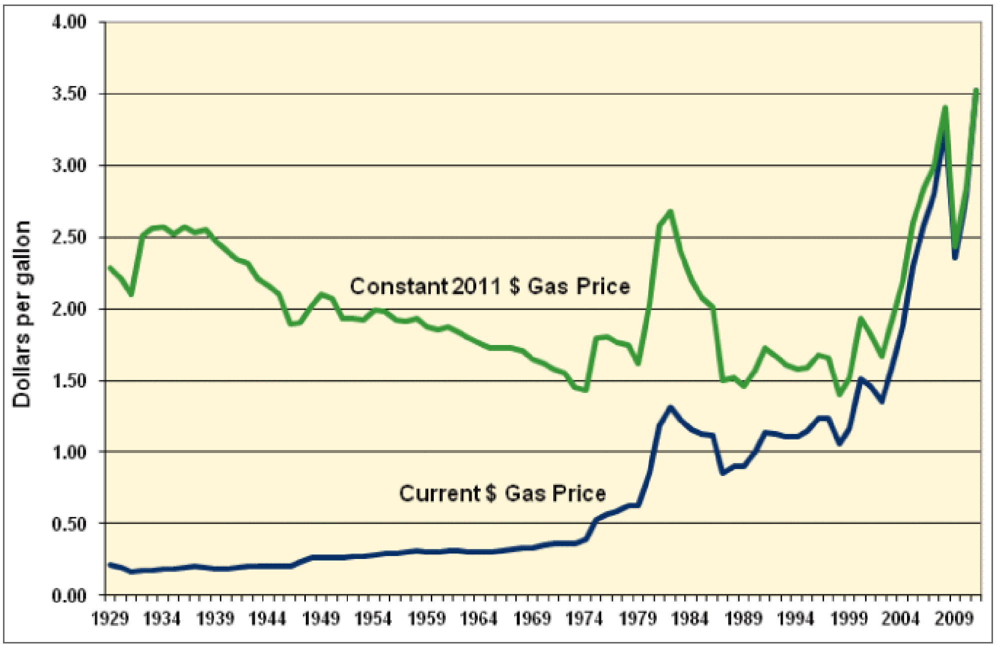

Figure 2.Evolution of the gasoline price in an actual price base and in original current prices. Source: US DOE (2012)

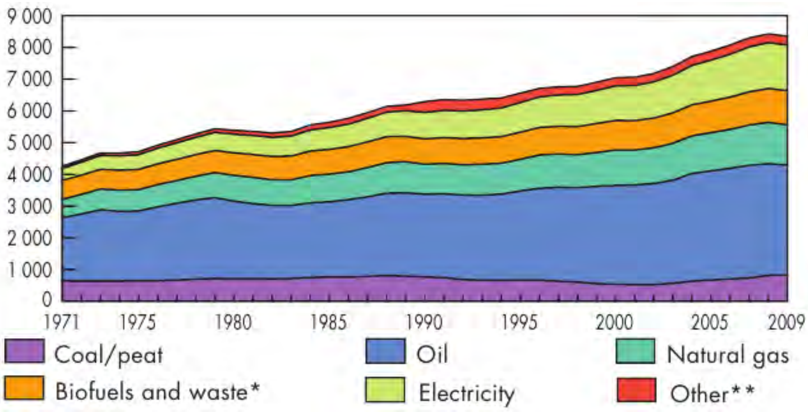

Figure 3.Word total final consumption from 1971 to 2009 by fuel (Mtoe).Source: IEA (2011).

2. AUTOMOTIVE ENERGY POLICIES

2.1 Policies in the USA

The north-American automotive energy policy started around 1970 with toxic additives based on lead and added to gasoline banned by government acts. The policies were tighten up in 2007 and reinforced in 2009 based on ACES (2009), these acts took strong achievable measures as the name itself shows (American Clean Energy and Security Act of 2009).

One of the main measure motivation was the national energy security, isolatingits economy from the regions of political instabilities that supplies oil, and this way make the inside economy of the country stronger to outside problems related to oil based fuels (Heywood et al, 2009).

The USA policy work in an integrated actions targeting to maximize the fuel economy and reduce the oil dependence and the Green House Gases (GHG) emissions at atmosphere, assembling a more sustainable economy.

From the view of Mechanical Engineering, the development have focus in the efficiency of the vehicle powertrain. In the trend of study, the Hybrid Electric Vehicles (HEV) are being well spread in the country and its continuous

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evolution is the Plug-in Hybrid Electric Vehicle (PHEV) as a manner to improve the fuel economy and diversify the power sources to supply the vehicle running (also have the extended autonomy electric vehicle that uses an internal combustion engine only as a generator for the battery pack. Ex.: Chevrolet Volt). Although, Evans (2008) and Nigro and Szwarc (2009) agreed that the Flexible Fuel Vehicle (FFV) when running only on gasoline ruin the vehicle purpose of using the alternative fuel (ethanol).

The government made a financial and academic partnership in the development of technologies to ensure that the improvements are in the way of the fuel economy objectives and alternative fuels, as the Progress Report (2010) says about the powertrain with better performance and fewer GHG emissions, as the Advanced CombustionEngine Research and Development.

The acts of government and research show the transition of technologies in transportation, because of the great presence of this sector in consumption of oil derivatives (gasoline and diesel), focusing in the environment and economy sustainability (US EPA, 2012). One way to see this development is the USA consumption of e thanol compared to the Brazil quoted as a pioneer in the broad use of ethanol and the Fig. 4 shows this from the International Energy Annual of 2004.

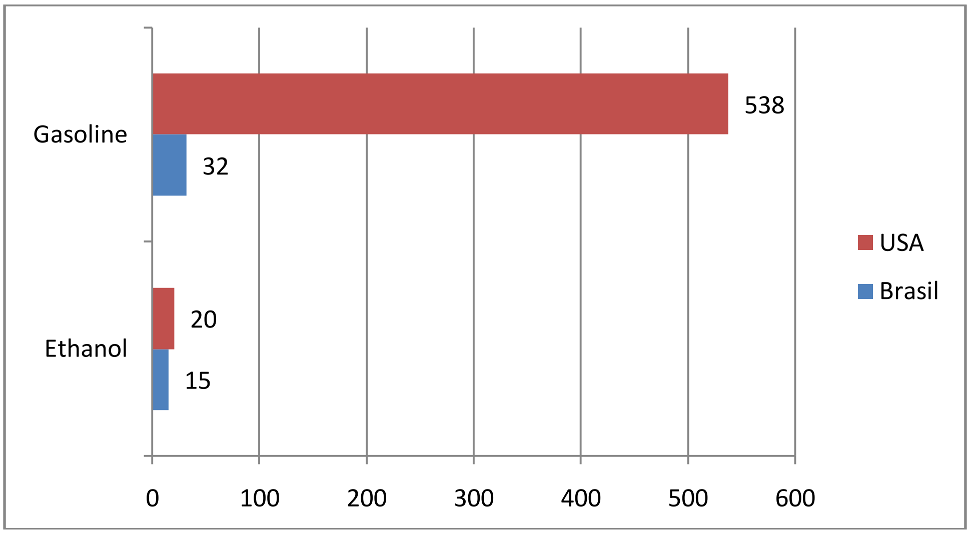

Figure 4.Fuel consumption in the US and Brazil (billions of liters). Source: EIA (2006).

2.2 Policies in the Japan

The initiatives about the automotive energy policy in Japan started in 1965, but in this country the research was directed to Battery Powered Electric Vehicle (BPEV), looking for a great independence from the oil because of its lack of resources, and the island condition aggravates the problem (Ahman, 2004).

In 1992, the north-american state of California had a demand of BPEV but it d idn't last to continue a good development in the issues of BPEV.

With the advancements made in BPEV, in 1995 s tarted in the market the HEV, that absorbed part of the development in electrical motors and batteries, and so the government included the HEV in support of taxes to reduce the use of fuel (gasoline) for the same reason of the USA, the national energy security and environment sustainability, the evolution in number of vehicles supported by government is shown in Fig. 5 (JEVA, 2002).

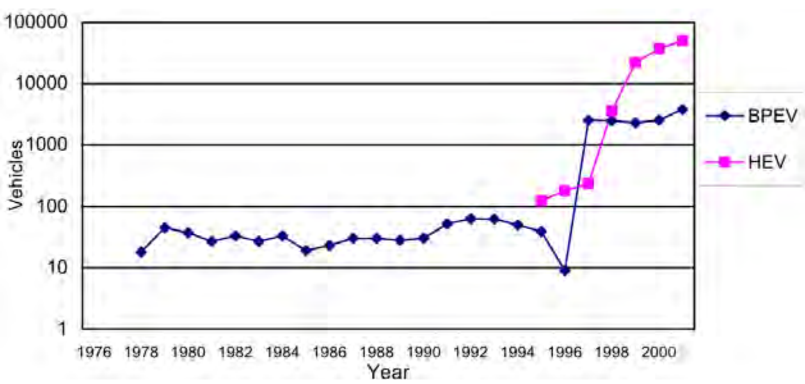

Figure 5.Statistic about the number of BPEV and HEV running in Japan. Source: JEVA (2002)

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The measures taken by the Japan were connected with major vehicle manufacturers for a directed development in the needs of the country, it showed a good interaction between government and manufacturers (which USA had some trouble in the partnership of government and manufacturers), and a good part of the standard evolution is due to the Top Runner program that keep making the evolution to better energy efficiency vehicles (Matsunaga, 2009).

The pioneering of Japan in transport technology like the BPEV and HEV in recent facts, ensure the partnership with USA and Europe Union (EU) in recent research for vehicle energy efficiency.

2.3 Policies in the Europe Union (EU)

The final report of CARS 21 (2012) program shows the evolution on the target policy of EU, highlighting the option for voluntary targets as showed in subtopic 2.4.

The EU automotive energy policy has a focus straight to vehicle efficiency in the use of fuels (fossil and renewable sources) and reduction in pollutant emissions by the integration of standard measures and policies to obtain results, based on a good project that drives the production and consumption towards the energy efficiency and avoid breach that can neutralize intended goals.

The measures are organized as the Onoda (2008) recommendations:

- An effective standard composition: Scope, test procedures, technological neutrality, regulatory flexibility;
- Standard stiffness to ensure the development of targets;
- Policies associated to standards: Labeling related to financial and tax incentives.

These are the main points as discussed in relaunched CARS 21 (2012), recommended and prepared for the sustainable and competitive development towards the targets established to 2020 and the whole integrated policy structure.

2.4 Comparison Among the Main Countries Automotive Energy Policies

The report form Onoda (2008) showed interesting information about, different policies in some countries and the results to deal with the evolution of standards and target, as shown in Tab. 1 for voluntary and regulatory programs.

Table 1.Results of regulatory standards and voluntary targets. Source: Onoda (2008).

	Regulatory standards			Voluntary targets		
	Year established	Target year	Outcome	Year established	Target year	Outcome
Japan	1999 2007	2010 2015	A*	1978 1993	1985 2002	F** F
European Union				1995 1999	2012 2008	F
United States	1975 2006	each MY	A			
Canada				1976 2005	Each MY 2010	A
China	2004 2004	2005 2008	A			
Australia				1978 1987 2005	1987 2000 2009	F F
Korea	2005	2006		2005	1996 2000 2009	

***A = achieved **F = failed**

At Fig. 6, a comparison of relative evolution among USA, Japan and EU presents in a good manner the degree of evolution in vehicles energy efficiency, and the good results in Japan's evolution about the Top Runner program and the

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standard based on weight not like USA and EU based on vehicles area (reflected on weight growth), that in EU accounting with the voluntary targets that showed a lack of success in the efficiency evolution.

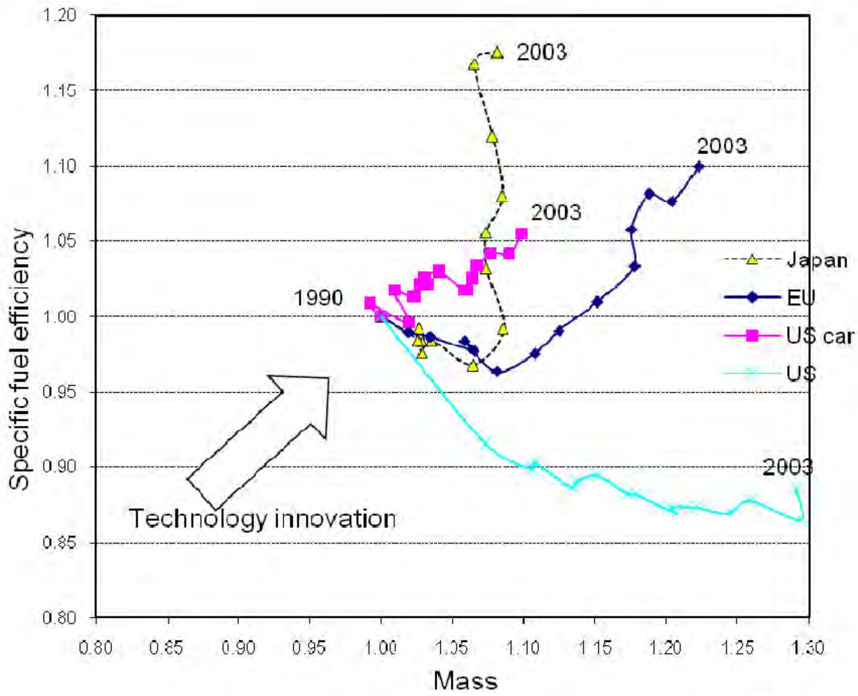

Figure 6.Fuel efficiency and mass trends (1990 = 1). Source: Onoda (2008).

3. THE USAGE OF FLEXIBLE FUEL VEHICLES

Many developments improved the efficiency and output power of engines. In the main subjects and recently can be quoted the variable valve timing and lifting electronic control, the Downsizing trend and the direct injection (DI), that each vehicle manufacturer have your abbreviation for a similar system in these developments that improved specific power of engine in kW/l or cv/l commonly used (International AE, 2002).

But a part of the development that is not so studied is the improvement in engines specifically for alternative fuels as ethanol, which in Brazil comprehends a big part of fuel use compared to the world average use of renewable fuels.

Starting in 2005 the sales Flexible Fuel Vehicles, but the technology for this application is only an adaptation for the engine to work properly with two fuels, gasoline and ethanol, so it isn’t a real advance in vehicle energy efficiency.

Some characteristics to pay attention in ethanol related to gasoline are fewer emissions as shown in Fig. 7 (Liao et al, 2005).

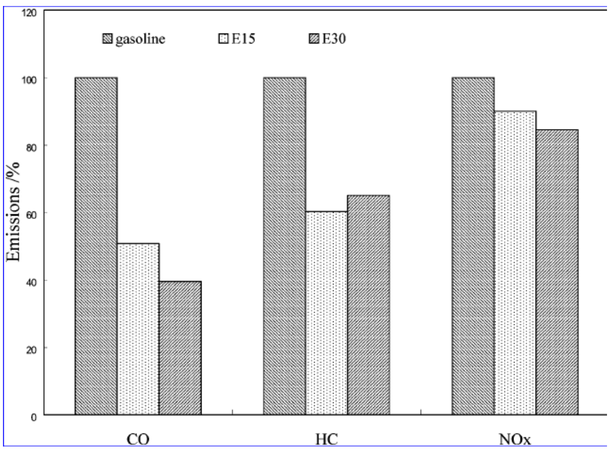

Figure 7.Emissions variations related to ethanol blend in gasoline (E15 and E30). Source: Liao et al (2005).

The flame speed faster in the use of ethanol, relating to the ignition timing and crank angle duration of the combustion, as can be seen in Fig. 8 from Liao et al (2005).

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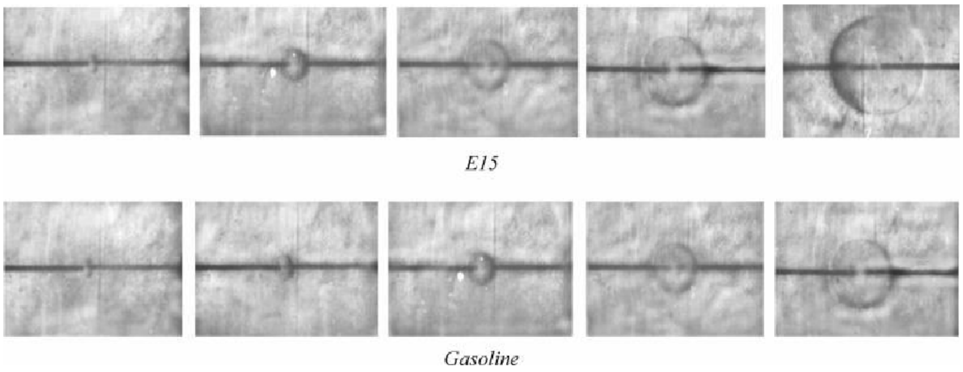

Figure 8.Flame core growth captured by schlieren camera for stoichiometric mixtures of E15 and Gasoline. Source: Liao et al (2005).

The paper of Yang et al (2010) through the Fig. 9 showed that, for the same fuel amount of ethanol, it releases more energy in the burning process, which can be related to the real situation of the ethanol engine has bigger power than the same gasoline engine displacement.

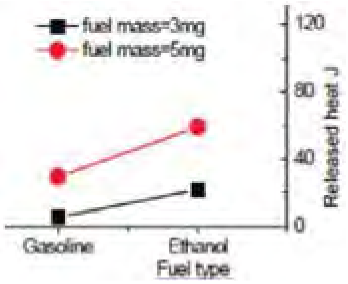

Figure 9.Comparison of fuels burn (NVO period) in stoichiometric mixtures. Source: Yang et al (2010).

And the experiment made by Cooney et al (2009) showed (Fig. 10) a very useful tool to analyze the use of ethanol with the compression ratio (c_r) and its knock limit, to see that many flexible fuel vehicles in Brazil (specially the popular ones) work in a region of combustion knock when fueled with gasoline, so this the paper analyze the approximate consequence of the use in a condition unsuitable for the fuel used (gasoline).

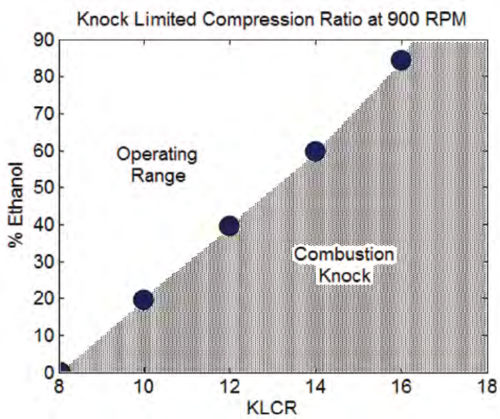

Figure 10.Experiment of a variable compression ratio engine and a variable blend of gasoline and ethanol. Source: Cooney et al (2009).

So, for the engine to work properly in the combustion knock region the ignition timing is altered from the optimal to avoid the knock, but this replace of the ignition timing leads to a lost in efficiency, less work from the cycle, for this condition the Fig. 11 shows the change in the cycle as other references (Vilanova, 2007, and Garcia e Brunetti, 1992).

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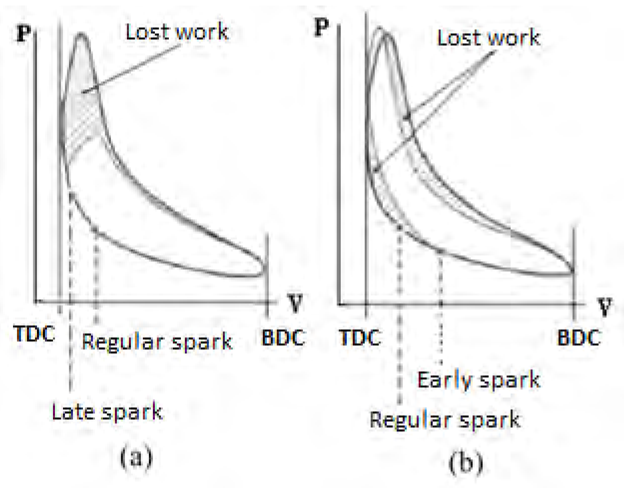

Figure 11.Influence of the ignition timing in the real Otto Cycle, (a) late spark, (b) early spark. Source: Giacosa (1988) apudMalfatti (2009).

Doing the calculus of thermal efficiency based on compression ratio and the constant **"*k*"** approximated to real conditions by the use of $k = 1{,}3$, as used by Heywood (1988) apudVilanova (2007) and Duarte et al (1996).

Using the compression ratio varying from 8 to 17 and the adiabatic constant (k) of 1,3 the Fig. 12 is built for the thermal efficiency based on the Eq. 1 below.

$$\eta_t = 1 - \frac{1}{c_r^{k-1}} \qquad (1)$$

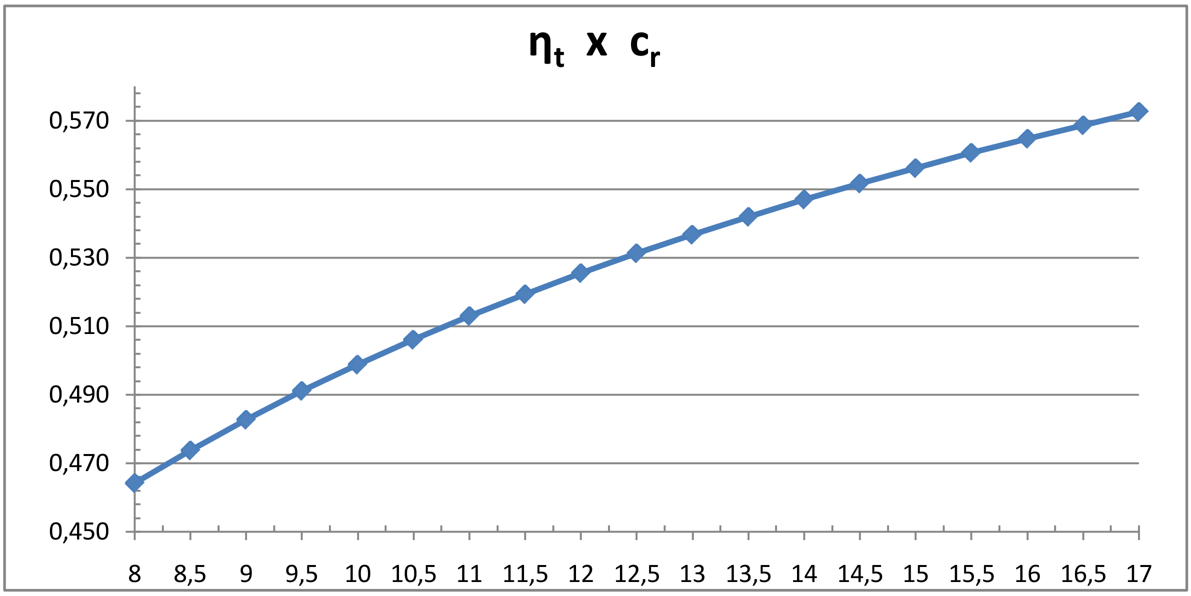

Figure 12.Thermal efficiency (η_t) versus the compression ratio (c_r) for $k = 1{,}3$.

Making reference based on the use percentage of gasoline and ethanol in Brazil shown in Fig. 13, assume that the percentage of gasoline use is the same percentage of people using only gasoline in the flexible fuel vehicles. So, from the Fig. 10 consider that the Brazilian gasoline is blended with 20% in volume of dry ethanol (E20) which mean by Cooney et al (2008) a compression ratio of 10 and an average compression ratio for FFV of 12,5.

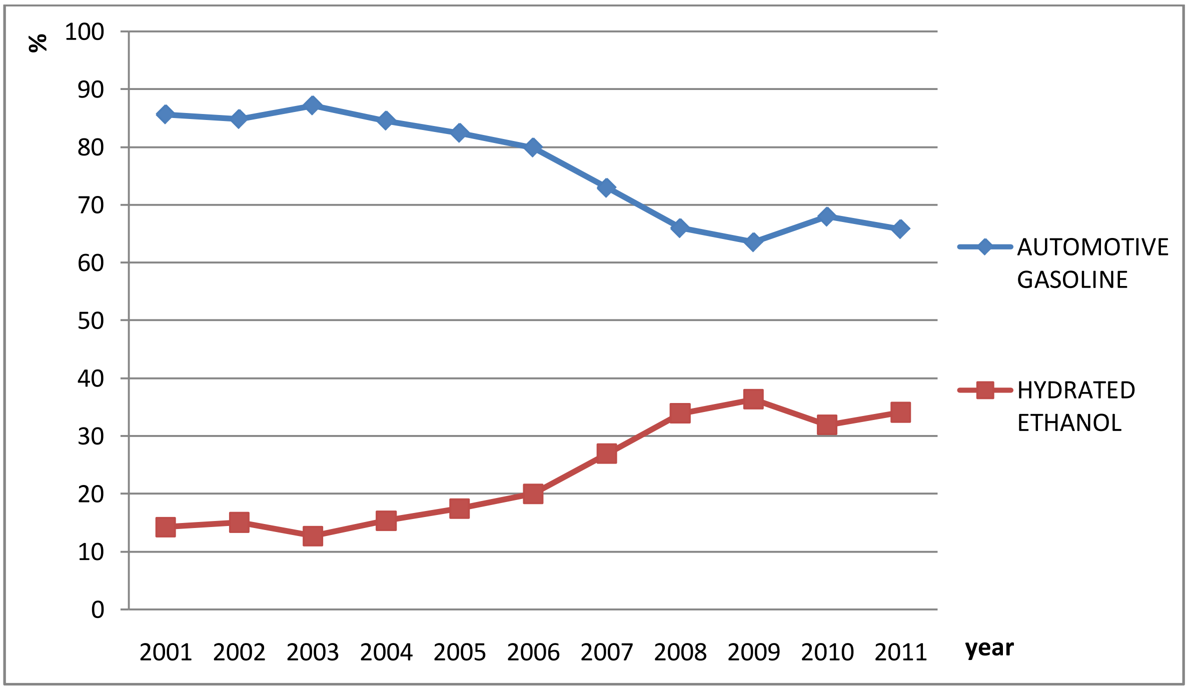

Figure 13.Use percentage of gasoline and ethanol in Brazil. Source: BEN (2011) e BEN (2012).

With these assumptions and the number of FFV sold, informed by ANFAVEA data, assume that the lost in thermal efficiency of the FFV using gasoline only is equal to percentage lost between the thermal efficiency of the c_r = 10 related to the c_r = 12,5 for the situation studied.

So the loss of efficiency can be expressed as a waste of gasoline adopting the Average Fuel Economy (AFE)about 14 km/l and an Annual Mileage (AM) of 10.000 km, as shown the volume in Fig. 14.

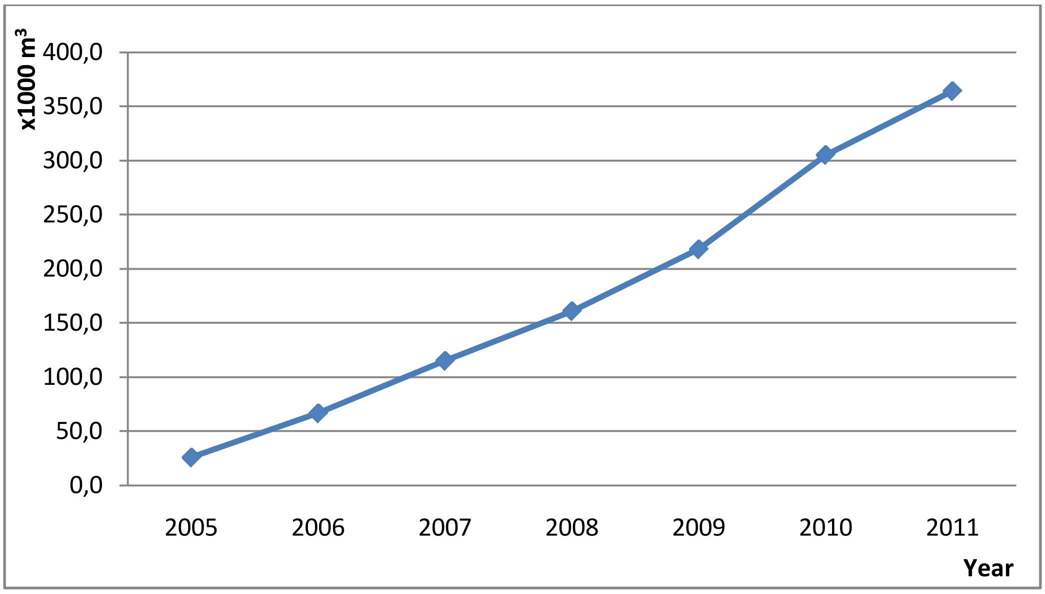

Figure 14.The waste of efficiency of a FFV of c_r=12,5 running only on E20 (c_r=10, AFE=14km/l and AM=10.000km).

Analyzing the evolution of the waste in Fig. 14, the data published about the importation of gasoline (Type A, pure, E0) and relating to the news of the reductions in the supplies of ethanol, can be associated this lost in vehicle energy efficiency with the over need in use and importation of gasoline as shown in Fig. 15, growing from 2009.

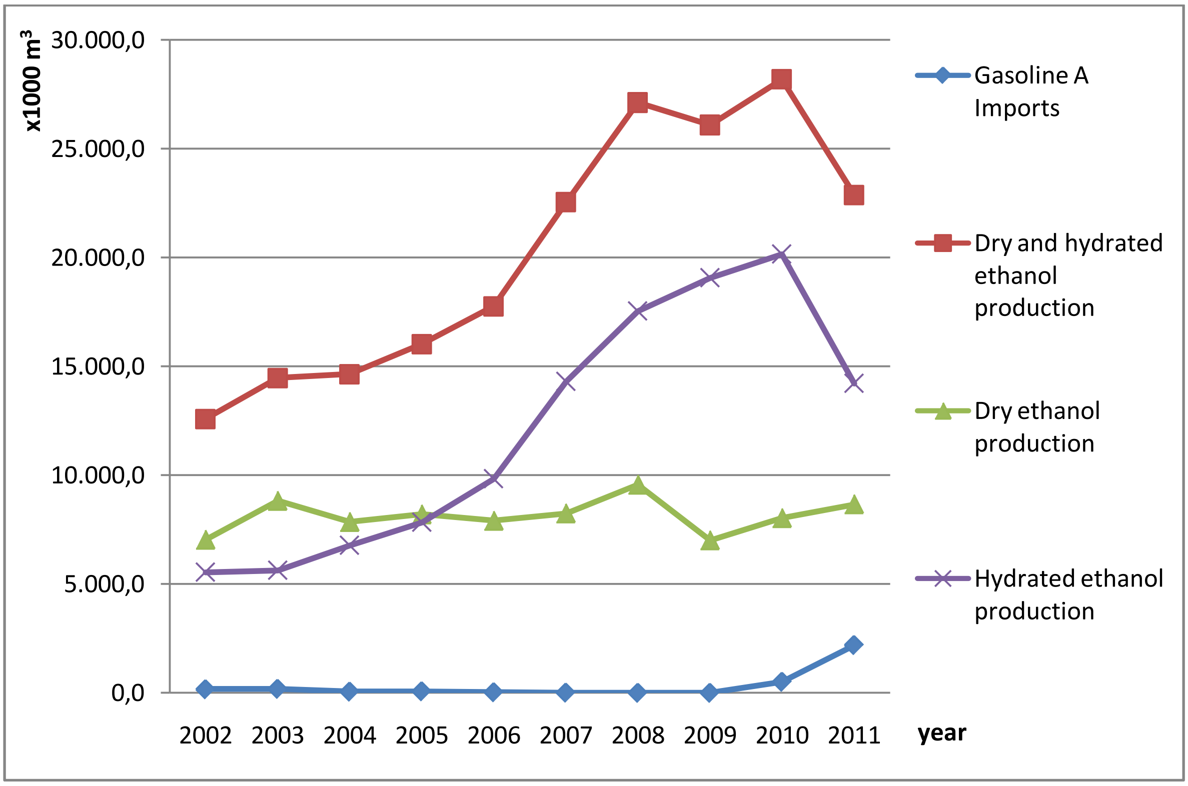

Figure 15.Evolution of fuel production and importation in Brazil. Source: BEN (2012) data.

4. CONCLUSION

The unadvised use of FFV running on gasoline and its waste of efficiency are against the movement of the automotive energy policies, as Heywood et al (2009) and Evans (2008) also called the attention, so for the Brazilian situation of automotive efficiency the development of engines running on specific fuels, for this is needed to equalize the developments in gasoline and ethanol engines with all the state of the art technologies.

The Brazilian government is starting measures to create and improve the automotive energy policy by vehicle energy efficiency, in this way have the Inovar-Auto Program and the research financial program InovaEnergia to start the path for more efficient vehicles (InovaEnergia, 2013).

But for the real evolution need to look to the international measures that worked well and improve it in Brazil, like integration of measures, policies, standards, incentives and an important development of cultural information and concern about the smarter and more cost-environmental choices.

5. ACKNOWLEDGEMENTS

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