Energy Consumption and Perspectives on Alternative Fuels for the Transport Sector: A National Energy Policy for Greece

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Abstract. During the last years, gasoline consumption, mainly for road transport, has dropped by more than 30% in Greece, while diesel consumption has seen a generally upward trend after 2013. In contrary, consumption of alternative fuels follows a positive trend. However, in 2016, the national use of Renewable Energy Sources in transport was at 1.4%, though the EU average was at 7,1%. The implementation of two National Action sub-Plans for Greece, one regarding the Renewable Energy Sources and the second about Energy Efficiency of Vehicles will boost the use of the alternative fuels and consequently the national production and distribution effort. This paper reviews the energy consumption over a period of years, defines the main pillars and describes the context of a rational energy policy plan for the transport sector.

Keywords: Transport · Energy reduction · Alternative fuels · Fuel consumption · Strategic plan · Energy policy

1 Introduction

Under the Renewable Energy Directive (European Commission 2018), Member States have to ensure that at least 10% of their transport fuels come from renewable resources. During the last five years, gasoline consumption, mostly used in road transport, has dropped by more than 30% in Greece, while diesel consumption has faced a generally upward trend after 2013. For railways, a 22% of the network is electrified placing Greece at the lowest European position of electrified railways. For maritime transport, an increasing use of crude oil over diesel is observed, which is the main maritime fuel for the rest of the EU (YPEKA 2016).

This paper is concerned with the potential for energy savings and the use of alternative fuels in Greece. It aims to define the main pillars of a national strategic plan for a transport energy policy and to describe a wider context by presenting actual cases.

E. G. Nathanail et al. (Eds.): CSUM2020, AISC 1278, pp. 347–356, 2021.
https://doi.org/10.1007/978-3-030-61075-3_34

2 Current Status of Alternative Fuels in Greece

Greece produces conventional fuels (gasoline, diesel, kerosene and fuel oil) for transport use and imports the remaining quantities to satisfy the demand. Production facilities also exist for the alternative fuels:

1. *Biodiesel*. The biodiesel production network in the Greek market consists of 16 producers and 7 importers (Government Paper of the Hellenic Republic 2016).
2. *Compressed Natural Gas (CNG)*. Natural Gas has been introduced to Greece by DEPA (2019) while FISIKON is the main CNG distributor, offering a network of 14 CNG refuelling stations mainly in large cities with another 7 planned to become operational in 2020 (FISIKON 2020).
3. *Liquefied Petroleum Gas (LPG)* is the most widely spread gas fuel used in transport in the country with more than 1000 available refuelling stations all over Greece.
4. *Electric energy*. Currently about 140 charging points are located in several spots in Greece supported either by FORTISIS, or Blink Europe (FORTISIS 2019; Blink Europe 2020), or in the form of pilot installations by petroleum companies. According to the Hellenic Institute of Electric Vehicles (2020), several spots existing along the national highways, but also in a number of public open area and parking spaces (e.g. Polis Park).
5. Biogas. According to the European Biogas Association (2018), Greece has 37 biogas production plants with all the volume being used for generating electric energy.
6. *Liquefied Natural Gas (LNG)*. An LNG storage facility is already in operation on Revithousa island for hosting imported volumes of gas. Two more installations are also planned and under construction in Alexandroupolis area. Nevertheless, due to the absence of LNG refuelling stations as well as the absence of LNG vehicles, LNG is not used as a fuel for transport activities in Greece.

Table 1 presents the total consumption and production of conventional and alternative fuels in the Greek transport sector for year 2010 and 2014. According to the data, the consumption of conventional fuels has an overall negative trend with fuel oil having the biggest drop of −42%. The only conventional fuel with a positive change of +4.3% in consumption was kerosene. Gasoline, has a negative change of −32% and diesel, predominantly used in Greek road, maritime and rail sector, faced a reduction of −22%. On the contrary, consumption of alternative fuels shows a positive trend with LPG having a 374% increase. On an annual basis, between 2013–2014, LPG usage presented a positive 6.9% trend. The usage of biodiesel also had positive increase by 8% with a yearly constant increase rate. This data reveals the effect of the last years' financial crisis. The decrease of the country's GDP as well as the establishment of high taxation on conventional fuels, led people to seek cheaper resources such as alternative fuels for transportation.

Table 2 presents an overall picture of conventional and alternative fuels' consumption. It is evident that the share of alternative fuels still remains small, compared to conventional fuels. Thus, alternative fuels in the Greek market contribute to only a very small share of 4 to 6% to the overall usage of fuels. It is worth stating that the

figures for alternative fuels for year 2010 and 2012 might be due to inaccurate data reported by official sources to Eurostat.

Table 1. Comparison of production and consumption figures of conventional and biofuels for Greece for the years 2010 and 2014 (ktoe).

	Fuel type	2010		2014		2018		% change	
		Production	*Consumption*	*Production*	*Consumption*	*Production*	*Consumption*	*Production*	*Consumption*
Conventional	*Gasoline*	4715	3867	4974	2643		2403	+5	−32.0
	Kerosene	–	234	–	178	–	220	–	+4.3
	Diesel	4642	2730	8145	2155		2504	+75	−22.0
	Fuel oil	–	441	–	258	–	340	–	−42.0
Alternative	*LPG*	771	46	831	222		242	+8	+374.0
	CNG	–	14.1	–	14		15	–	−0.9
	Biodiesel	112	124	142	134	151	159	+27	+8.0

Elaboration from: (ΥΠΕΚΑ 2016), and (Eurostat 2016)

Table 2. Consumption of conventional and alternative fuels for Greece (2010–2014).

	Total consumption (ktoe)				
	2010	2011	2012	2013	2014
Conventional fuels	8056	7114	6153	5970	6061
Alternative fuels	188	320	178	349	383
Share of alternative fuels	2.3%	4.3%	2.8%	5.5%	5.9%

Elaborated from: Eurostat (2016)

3 Fuel Consumption Per Transport Mode

3.1 Road Transport

The main conventional fuels used in road transport are gasoline and diesel, while biodiesel, CNG, LPG and electric energy constitute alternative fuels used in Greece. Figure 1 presents a comparison of fuel consumption for diesel and gasoline between Greece and EU 28. Gasoline consumption in Greece seems to have gradual declined by −46.2% from 2010 (3.847 ktoe) to 2018 (2.403 ktoe). Although, road diesel consumption seems to decline after 2010 from 2.437 ktoe to 1.623 ktoe in 2012, in the following year consumption seemed to begin recovering again. Despite the fact that road diesel consumption for Greece and EU 28 share a similar pattern, the reduction in consumption for Greece is greater to that for Europe. The fluctuation of gasoline and diesel consumption seems to have been affected by the financial state of the country as well as the imposed taxes on fuels. Hence, based on the presented data, gasoline is the predominant fuel used for road transport in Greece while diesel comes second, which is the exact opposite to the European figures where diesel is the main fuel consumed. The recovery of diesel in 2012 is a direct result of the policy regarding diesel usage that Greece has followed over the years for not allowing diesel passenger cars in urban

areas due to national smoke standards. In late 2011 the Greek government has allowed the usage of diesel vehicles that meet Euro 5 and 6 regulations.

Another interesting fact is that according to Table 1 production figures of gasoline are much higher than the consumption from the road transport sector. This means that the country can export gasoline, something that is also verified by Eurostat (2018) statistical data of the country's exports.

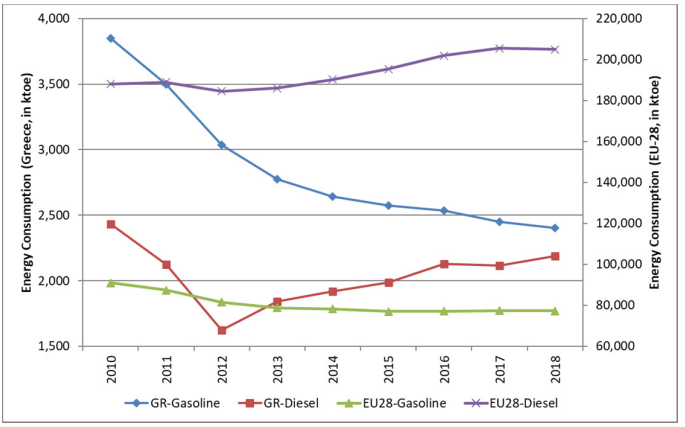

Fig. 1. System architecture Energy consumption for diesel and gas in the road transport sector during 2010–2018 for Greece and EU28 (in ktoe). Source: Elaboration on data from Eurostat (2018).

Figure 2 presents a comparison on fuel consumption for alternative fuels between Greece and EU 28. Overall, in both cases consumption of alternative fuels shows a positive growth. LPG seems to be an exception to this rule especially for years 2010 and 2012 where significant dropdowns have occurred, possibly as mentioned earlier, due to inaccurate reported data from official sources of Eurostat. CNG consumption is very low with figures of 13–15 ktoe, except of 2016 when a significant growth happened (19 ktoe). Low consumption figures are also shown for the EU28 with both pattern lines sharing similar characteristics. Finally, values for electricity with the exception of 2 ktoe reported in 2014 (Eurostat 2018).

3.2 Rail Transport

Diesel and electric energy are the main types of fuels used in the Greek rail sector with diesel being the predominant fuel. The highest diesel consumption figures of 41 ktoe are reported from 2014 with the remaining years showing fluctuations (Fig. 3, left side). Consumption of biodiesel started on year 2013. On the contrary, electric energy comes at the first place with a large difference in terms of consumption for the EU28 member states (Fig. 3, right side). This trend could become reality in Greece as well when the railway network along Athens-Thessaloniki-Eidomeni corridor will be electrified.

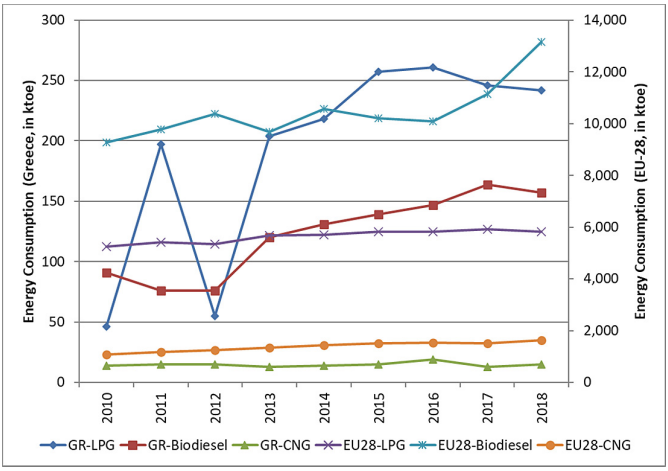

Fig. 2. Energy consumption of alternative fuels in the road transport sector for Greece and EU28 for 2010–2018 (in ktoe). Source: elaboration on Eurostat (2018).

Greece remains one of the few countries in the EU without electrification in the entire rail network. Therefore, biodiesel should be seen as an alternative until further electrification of the entire network. However, biodiesel in the rail sector is low even at an EU28 level (Fig. 3 right side).

3.3 Air Transport

The main fuels used in aviation in the Greek market are gasoline and kerosene (for piston driven propeller aircrafts and turbine driven aircrafts, respectively). According to Eurostat (2018) use of aviation gasoline in Greece is very low compared to kerosene and is only used in domestic aviation with quantities of 2–3 ktoe per annum. According to Fig. 4, the consumption of aviation kerosene for domestic flights shows a 6% decrease between 2010 (234 ktoe) and 2018 (220 ktoe).

3.4 Maritime Transport

Maritime diesel and fuel oil are the main fuels used in the domestic Greek maritime sector according Fig. 5 (left part). Figure 5 (right part) presents the respective figures for the EU28. After 2011 the consumption of maritime diesel in the Greek market shows a decrease of - 31% in 2014, topped by a −42% decrease in fuel oil usage in 2014 from a maximum value of 440 ktoe in 2010. Maritime diesel and fuel oil usage seem to be decreasing for both Greece and the EU 28. A significant difference between the compared markets is that in the case of Greece, fuel oil is predominantly used for domestic maritime transport compared to the EU28 figures where the opposite occurs. In the latter case maritime diesel comes in first position in terms of consumption with almost doubled figures compared to fuel oil. An interesting fact worth noting is that the consumption of fuel oil for the Greek domestic maritime transport represents the 27–

30% (depending on the year) of the total EU28 consumption. Furthermore, Greek maritime diesel fuel consumption represents the 6–7% of the equivalent EU28 consumption.

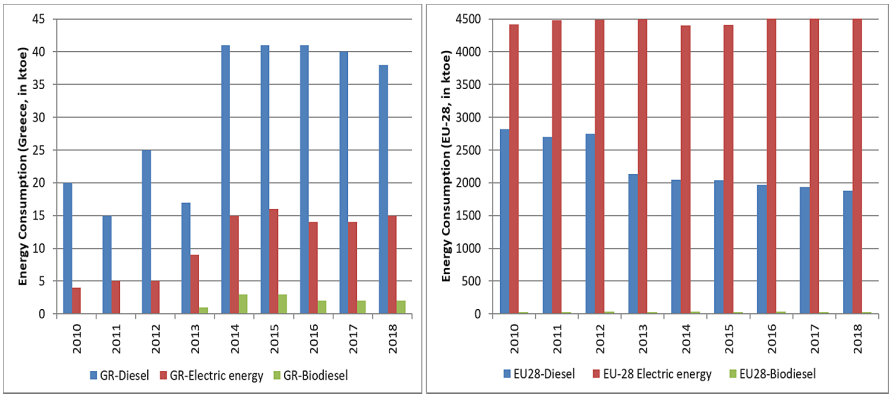

Fig. 3. Consumption of conventional and alternative fuels used in the Greek rail sector (left part) and in the EU 28 rail sector (right part) in the period 2010–2018 (ktoe). Source: Elaboration on data from Eurostat (2018).

Fig. 4. Consumption of conventional fuels in Greek air transport 2010–2018 (ktoe). Source: elaboration on Eurostat (2018).

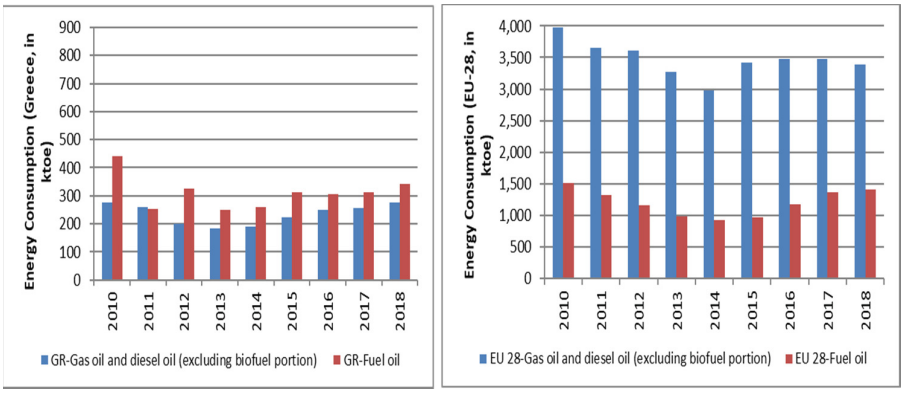

Fig. 5. Consumption of conventional fuels (ktoe) in the domestic maritime transport sector in Greece (left part) and in the EU28 (right part) for the period 2010–2018. Source: elaboration on data from Eurostat (2018).

4 Towards a Rational National Energy Policy for the Greek Transport Sector

4.1 Parameters to Be Taken into Account for a National Transport Energy Policy

The first and foremost element of a National Transport Energy Strategic Plan would be the delineation of the objectives and goals of the national policy in relation to a number of parameters that will define the energy mix for the transport sector in the coming 30 years or so (until 2050). These parameters include:

A. The national targets for the reduction of transport related GHG emissions in all transport sectors. For the EU member countries in the region, these targets would be largely set by the EU's policies and legislation already set in place as mentioned in the beginning. For the other countries in the region each government should by 2022 define these targets within the so-called *Nationally Determined Contributions – NDCs* that have to be defined as part of the COP21 Paris Agreement of 2015.
B. National targets for specific energy mix to be used by each transport mode.
C. The targets and objectives regarding the fleet mix i.e. the types of vehicles that will be allowed to circulate in the country. A number of European countries are already in the process of proposing the banning of vehicles with internal combustion engines in urban areas after 2040.

4.2 Supporting the Production and Use of Renewable and Alternative Fuels

In Greece, a wide range of prospects and potentials exist for the development and utilization of renewable and alternative fuels. Table 3 presents alternative fuels currently present in the Greek market including those with future potential and their relation to the previous list of parameters.

Table 3. Alternative fuels and their potential in Greece.

Fuel type	Potentials	Parameter
LPG	The production and distribution infrastructures of LPG is continuously expanding and has already reached the so called "critical mass"	A, B
Biofuels	Their future use is modest while its production seems - at present - to be low. The production of second-generation *biodiesel* coming from fried oils could be another solution. This prospect is quite important and with the appropriate support from the government, it could lead to a future innovative solution for alternative fuels	A
	Biomethane derived from upgrading biogas could become an alternative fuel although it will require extensive capital investment the creation of upgrade plants	A
	Ammonia derived from biomass, energy crops, natural gas or renewable energies can be used as fuel directly on internal combustion engines or fuel cells and has attracted a lot of attention in terms of its usage as a future maritime fuel (Lloyd's register 2017). Greece could potentially become a producer of this fuel	A, B
Natural Gas	A relatively new transport fuel in Greece that has not yet reached critical mass in terms of distribution stations although there are good prospects of its use. Therefore, establishing a pricing policy in the first years of expansion will be crucial for attracting attraction of new users	A, B
Hydrogen	Production and distribution units for hydrogen do not exist in Greece. Nevertheless, pilot production units exist at the Centre for Research and Technology Hellas (CERTH) and the Center for Renewable Energy Sources and Savings (CRES). Hydrogen is considered to be the most promising fuel for future transport systems. It can be produced either from water by electrolysis provided that electricity from renewable sources is used or from more innovative techniques, such as Hydrosol a method developed by Centre for Research and Technology Hellas (CERTH), where hydrogen is produced by CO2 and water under the impact of sun energy (Pagliaro et al. 2010). Aspects of the production, provision and transport of hydrogen in Greece have to be considered with particular attention while investment issues have to be promptly planned by state and industry	A, B, C
Biomass	The available reserves of agricultural residues that could be used to produce biomass in Greece are significant (Christou 2013). Available agricultural and forestry residues that can be utilized, equal to 3–4 billion tons of oil per year and correspond to the 30–40% of oil amount that is annually consumed in Greece. Such figures show impressive potentials that cannot be ignored	A, B

4.3 Promotion of Energy Friendly Modes and Clean Vehicles

Energy "friendly" or "clean" transport modes, are defined as those that consume energy produced from "energy friendly" ways and do not intensify the problem of climate change. Such modes are: i. all electrified rail or road transport means since the electricity they use is produced from hydroelectric or solar energy or other "energy friendly" sources, ii. the vehicles that use renewable or alternative fuels and iii. transport on foot or by bicycle. Also, all public transport means using hydrocarbon fuels could be considered as energy friendly transport modes concerning their high level of passengers' service and their consequent low energy consumption per passenger. However, they should be the first to be considered for conversion to using alternative energy fuels in the future.

The promotion of energy "friendly" or "clean" transport modes must form a systematic and permanent aspect of transport and energy policies for successive Greek governments. Incentives, within the context of this policies, could include: a. reduction of car tax for "clean vehicles", b. reduction of tax or public subsidies for purchase of friendly vehicles, c. reduction of tax of renewable fuels, d. ease of licensing and launching of stations for the supply of environmentally friendly fuels through granting procedures, e. update of the compensatory measures for drivers of "friendly vehicles" in urban areas (e.g. free access in areas with traffic restrictions, special parking places or free parking, free parking places for electrical cars). In addition, vehicle importers in Greece will need to show more willingness and offer additional electric vehicle models in the market compared to the limited choices that currently exist.

5 Conclusions

Greece must make an intensive effort for the improvement of energy resources in the transport sector and the larger use of renewable and alternative fuels following the corresponding EU Guidelines.

It is of importance now to integrate, and plan renewable and alternative fuels sources within a National Transport Energy Plan that will be in line with the country's general Transport Policy and Energy Policy as well as to all associated policies for dealing with climate change. This Plan, should, among others, include: (i) Quantified targets in relation to the fuels in use in transport sector in the future (target years 2030, 2050). (ii) Specific measures to be taken for increased production and use of renewable and alternative fuels in Greece incorporating emissions from field to tank in order to estimate alternative fuel pathways that are suitable for the country. (iii) Specific measures for increased use of energy friendly means of transport and clean vehicles (special emphasis in electric cars). (iv) Targets for improvement of the Greek energy mix with larger penetration of renewable energies. (v) Specific measures for creating production facilities for alternative fuels using renewable energies. (vi) Collection and study of statistical data regarding the capacity that the different regions in Greece have in terms of renewable energies. (vii) Insight to social behavioral issues and user acceptance of clean sources of energy in transport.

Boosting the national production and use of "clean" fuels in transport is also very compatible regarding the techno-economic opportunities of the country as well as the responsibilities towards the European and international treaties. Such a prospect will give the country a powerful development perspective. Although the energy intensity of Greece has almost reached the European average, there is still significant room for energy savings and rational use of energy in transport.

Acknowledgements. We would like to thank Prof. G. Giannopoulos for his valuable contribution, by providing us relevant literature for Greece.

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