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The Role of Sustainability-Related Strategies on the Biofuel Industry: Trends, Prospects and Challenges

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ABSTRACT
The aim of this study is to elucidate the sustainability-related strategies on the biofuel industry. Our empirical analysis is based on a time series data set covering diesel demand in Greece over the period 1978–2014 and on the basis of these estimates we make forecasts for biodiesel consumption in the coming years (2015–2030) under three alternative scenarios. Our approach utilizes unit root testing to investigate possible co-integrated relationships among the sample variables. The empirical findings indicate that diesel demand is income and price inelastic in both the long and the short run, while biodiesel demand seems to have an upward trend over the simulated period. We argue that the importance of biofuel in the Greek energy balance will change the form of the existing business strategies towards issues such as sustainability, green entrepreneurship and corporate social responsibility to achieve the environmental goals set by the EU Energy Roadmap 2050. Copyright © 2018 John Wiley & Sons, Ltd and ERP Environment

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Introduction

RECENT OIL PRICE HIKES AND A GLOBAL CONCERN REGARDING THE LIMITED LIFE CYCLE OF PETROLEUM HAVE TURNED THE ATTENTION of policy makers and government officials towards environmentally friendly energy sources that take account of sustainability (Sharma and Ruud, 2003; Amran *et al.*, 2015). These sources include solar, wind, ocean wave and tidal flow, geothermal and biofuels, which at their initial outbreak were considered to be society's liberator from liquid fossil fuels. However, long disputes regarding biofuel viability, together with controversy about their actual sustainability, has challenged their acceptance globally (Smink *et al.*, 2015).

The three main types of biofuels are biodiesel, ethanol and biogas ('first-generation' biofuels). Biodiesel is a diesel substitute and is produced through transesterification of vegetable oils, residual oils and fats; with minor engine modifications, biodiesel can serve as a full substitute for diesel. Bioethanol is a petrol substitute and can be used as a full substitute in so-called flexi-fuel vehicles. It is derived from sugar or starch by fermentation. Bioethanol

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can also serve as a feedstock for ethyl tertiary butyl ether, which blends more easily with petrol. Lastly, biogas (biomethane) is a fuel that can be used in petrol vehicles with minor adaptations. It can be produced through the anaerobic digestion of liquid manure and other digestible feedstock. Biodiesel, bioethanol and biogas are produced from substances that are also used for food.

More recently, 'second-generation' biofuels have been produced in a more systematic way. These fuels are produced from biomass in a more sustainable way, which is truly carbon-neutral or even carbon-negative in terms of its impact on carbon dioxide (CO_2) emissions. At present, the production of such fuels is not cost-effective because there are several technical barriers that need to be overcome before their potential can be realized. Plant biomass represents one of the most abundant and underutilized biological resources on the planet, and is seen as a promising source of material for fuels and raw materials. As it is most basic, plant biomass can simply be burned to produce heat and electricity. However, there is great potential in the use of plant biomass to produce liquid biofuels. However, biofuel production from agricultural by-products can satisfy only a proportion of the increasing demand for liquid fuels. This has stimulated great interest in making use of dedicated biomass crops as feedstock for biofuel production.

Because the biofuel industry is not currently maintaining its recent dynamic growth on a global scale, researchers have begun to suggest that biofuels should omitted once efficient state-aided policies are in place and be reinvented by applying marketing strategies as with any other product. Sustainability, the zeitgeist of our times, can be linked to biofuels with great success, as they are renewable, cleaner, harm the environment much less than fossil fuels and overall are satisfactory in terms of transportation efficiency. Moreover, important new opportunities, apart from the traditional road transportation sector, which accounts for almost all production of biofuels worldwide, in the aviation and the marine sectors are emerging.

Despite growing concern regarding the use of biofuels and their impact on environmental efficiency and sustainability, most studies have largely overlooked these issues. Zapata and Nieuwenhuis (2009) analysed Brazil's experience with biofuels (ethanol and biodiesel), focusing on the role of the government as the main driving force towards the implementation of alternative locally produced liquid fuels. Their study contributes to the growing environmental debate favouring either traditional command-and-control measures or economic incentive instruments (i.e. green taxation, tradable permits, subsidies, etc.) by taking into consideration the role of biofuels. Spetic *et al.* (2012) show five critical areas that Brazil's sugarcane-based ethanol industry could capitalize on to incorporate sustainability into company strategies. They used a qualitative research method to extrapolate from data. They argue that existing sectoral innovation systems in Brazil could be used to channel sustainability-driven innovations.

The present study contributes to this literature in many ways. First, it tries to link the biofuel industry with sustainability-related strategies, an issue that has been neglected. Second, it builds an econometric framework covering diesel demand in Greece over the period 1978–2014 and on the basis of these estimates we make forecasts for biodiesel consumption in the coming years under three different policy scenarios. Lastly, our study is the first to our knowledge in which biodiesel demand in Greece has been econometrically estimated.

The rest of this paper is organized as follows. The next section describes the Greek biofuel industry and poses the main research questions. In the subsequent section, we describe the data and the empirical methodology used in this study to estimate biodiesel demand, and then analyse the three scenarios regarding biodiesel demand until 2030. Lastly, the paper concludes with some policy implications.

The Greek Biofuel Industry

The world supply of biofuels is dominated by bioethanol, holding a market share of about 80% in 2010, which is estimated to decline to 71% by 2030. The other dominant biofuel, biodiesel, currently has a 20% share and is expected to decrease by approximately 40%, being substituted by biomass to liquids. Despite these considerations liquid biofuels in Greece are virtually identical to that of biodiesel, because there is no bioethanol production locally and Greece does not import any bioethanol. Although there is European legislation and a regulatory framework regarding bioethanol, it seems that no targeted policies aiming to promote the production, import and consumption of

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bioethanol have been made. We will endeavour to investigate the real causes underlying this critical discrepancy compared with other European countries.

The mixing of biodiesel with diesel began in Greece at the end of 2005 at a rate of 2.5% and is now regulated at 7%. The first commercial volume output of biodiesel was produced by Hellenic Biopetroleum S.A. Since then, the annual quantity to be distributed for blending with diesel fuel in the Greek market has been defined by a Ministerial Decision of the Ministry of Environment and Energy.

A Biodiesel Allocation Programme has been in place since then. Each year, the programme determines the amount of biodiesel to be allocated for domestic production and importation. The beneficiaries of this allocation are primarily domestic producers and secondarily two local refineries and a few local petroleum marketing companies that have been admitted to the list. Following a complex calculation system, the allocation quantity per beneficiary is determined and this holds to any party wishing to blend diesel with biodiesel in Greece. It is evident that this system is restrictive for all stakeholders (producers, refiners, blenders or marketers), creates entry barriers and promotes the domestic production of agricultural and biodiesel.

In 2015, among the 18 companies that qualified as beneficiaries of the annual volume, 12 were producers and six importers. The 12 producers accounted for 93% of the volume (approx. 130 000 m^3, i.e. 130 million litres). However, their installed capacity is approximately seven-fold the total annual volume. It is worth noting that the capacity of the largest producer, Agroinvest S.A., is more than double the total annual volume and that the capacities of the second, third and fourth largest producers range from 80 to 65% of the total annual volume. IOt is therefore clear that the installed biodiesel production capacity in Greece is asymmetrical with regard to current local demand and underutilized, with only 14.4% being used for the local market. It is also clear that there is significant potential, at least in terms of capacity, for exports and/or for higher blending mandates (currently the blending mandate is set at 7%).

Empirical Framework

Data and Methodology

Following the specifications of Bentzen (1994), Samimi (1995), Eltony and Al-Mutairi (1995), Ramanathan (1999), Alves and Bueno (2003) and Polemis (2006), a log-linear form using per-capita income (gross domestic product, GDP), real energy price of diesel and per-capita diesel vehicle fleet as independent variables is used in the empirical analysis. The following specifications for the long-run road demand for diesel are used:

$$\ln(\mathrm{DCON}_t) = b_0 + b_1 \ln(\mathrm{GDP}_t) + b_2 \ln(\mathrm{DPRICE}_t) + b_3 \ln(\mathrm{RPGASOL}_t) + b_4 \ln(\mathrm{DFLEET}_t) + u_t \quad (1)$$

where DCON_t is the dependent variable and represents the per-capita diesel consumption for road transport at time t, GDP_t stands for GDP per capita income at time t, DPRICE_t stands for the real price of diesel (final one – including taxation) at time t, $\mathrm{RPGASOL}_t$ is the real price of petrol (leaded and unleaded), DFLEET_t stands for the per-capita diesel-engine vehicles at time t, and u_t stands for the disturbance term at time t. The reason for using diesel-engined is to capture diesel use and any possible substitution effect with other 'competitive' fuels (i.e. petrol, autogas). Note that the inclusion of this variable in diesel demand-driven models is well documented in the empirical literature (e.g. Bentzen, 1994; Polemis, 2006). The positive and negative signs on top of the independent variables indicate the respective relationship with the dependent variable they are expected to have. The effect of other variables, such as the price of liquefied petroleum gas (LPG) for vehicles (autogas) has not been studied in the present analysis due to severe data restrictions. More specifically, the use of LPG as an automotive fuel was first introduced in Greece around 2000. Therefore, a complete data price series for the whole sample period is not available. In addition, there are virtually no vehicles that use only autogas in Greece except for one or two models that account for insignificant sales. Therefore, automotive LPG has a complementary use as compared with other fuels such as petrol and diesel. Lastly, no official estimates are available measuring the numbers of vehicles that have turned to a mixed gasoline and liquefied gas system. For these reasons, use of the above variables was not dictated by the sample data.

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The data used in the empirical analysis are national time series data expressed in natural logarithms covering the period 1978–2014. The relevant period was dictated by data availability. Consumption of diesel oil (DCON) is measured in kilograms per capita. These data were drawn from the International Energy Agency.[1] Per-capita GDP is expressed in constant 2009 prices, is measured in euros per capita and is obtained from the Eurostat Database.[2] Diesel price (DPRICE) and petrol price (RPGASOL) include all taxes and duties (VAT, excise duty, etc.) and are drawn from the Energy Prices and Taxes database (IEA).[3] The latter includes annual and quarterly end user industry and consumer prices as well as annual, quarterly and monthly crude oil spot prices, oil product spot prices and import costs by crude stream. The end user prices cover the main oil products, gas, coal and electricity. This variable is expressed in euros per litre and has been deflated by the consumer price index (2009 = 100). Finally, the variable that measures the per-capita fleet (DFLEET) of diesel engine vehicles (buses, heavy commercial vehicles and passenger cars from 2011) is obtained from the database of the Association of Motor Vehicle Importers Representatives (AMVIR)[4] and is expressed in vehicles per capita.

Unit Root Testing

To examine the order of integration, we apply a series of diagnostic tests both to levels and differences of these variables [Augmented Dickey–Fuller, Phillips–Perron, Kwiatkowski–Phillips–Schmidt–Shin (KPSS) and Ng–Perron tests]. The tests show that the null hypothesis of a unit root cannot be rejected in levels for all the variables. Looking at the results of the KPSS test and more specifically at the nt statistic of KPSS (test of intercept and time), we observe that GDP appears to be stationary at levels. However, this observation of KPSS is not in line with the alternative test, i.e. the nμ statistic (test of intercept), which indicates an absence of stationarity and is in line both with the graphical illustration and the full tests of the Augmented Dickey–Fuller, Phillips–Perron, KPSS and Ng–Perron methods. Thus, we adhere to our finding of an absence of stationarity at levels.

Following the examination of stationarity at levels, we apply the tests at first differences. The results of each variable test support that the stationarity hypothesis cannot be rejected. More specifically, the stationarity hypothesis regarding the variables GDP, DPRICE and DCON cannot be rejected at the 10% level of significance, whereas regarding DFLEET, it cannot be rejected at 5%.

Co-Integration Analysis

We continue our empirical analysis with the elaboration of co-integration techniques in our model to examine whether there is long-run (structural) co-movement of the variables. Since non-stationary time series result in spurious regressions and hence do not allow statistical interpretation of the estimations, we ought to apply co-intregration techniques, here the Johansen methodology of maximum likelihood. Estimation of trace statistics provides good evidence that one vector of co-integration between the model's variables exists. Summarizing the results of the co-integration analysis, it is clear that the null hypothesis (no co-integration) is rejected at the 1% level. In other words, one co-integration vector exists at 1% level of statistical significance.[5]

Long-Run Estimations

Having defined that our series are all stationary at their first differences and also co-integrated, our next step is to assess the long-run elasticities of the model. We follow the two-step Engle and Granger methodology by estimating an error correction model (Engle and Granger, 1987). The main reason for using this approach instead of using a

[1]International Energy Agency, http://www.iea.org/bookshop/661-Energy_Balances_of_OECD_Countries
[2]Eurostat, http://ec.europa.eu/eurostat/data/database
[3]International Energy Agency, http://www.iea.org/statistics/onlinedataservice/
[4]Association of Motor Vehicle Importers Representatives, http://www.seaa.gr/en
[5]The results from the unit root and co-integration tests are available upon request.

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vector autoregression model (VAR) is that the latter is more sensitive to the number of lags that can be used (Polemis and Dagoumas, 2013).

Our first observation concerns the statistical significance of the independent variables (Table 1). All are significant at the 1% level, except for the constant term (*C*), which is not statistically significant, but does not affect the quality of the model. The fact that the estimated coefficients are highly statistically significant supports the validity of the model. With reference to the diagnostics carried out for the long-run regression, we have performed tests looking for autocorrelation and heteroscedasticity through Durbin–Watson, Lagrange Multiplier (LM), White and Arch tests, the results of which reject their existence (of autocorrelation and heteroscedasticity). Moreover, we applied the Jarque–Bera test to our sample data and found that it follows a normal distribution.

Finally, the Chow breakpoint tests for the years 1992 and 2003 – both considered as milestones for the local oil product market, since deregulation of the market first began in 1992, was completed in 2002 and the ban on diesel was lifted in 2011 – show that there have been structural breaks in diesel demand as expected. An alternative approach would be to estimate shot-run oil shocks in the manner of Kapetanios and Tzavalis (2010). However, this kind of analysis is beyond the scope of this paper.

Regarding the estimated coefficients, they do have the anticipated signs. More specifically, the income effect (GDP) is positive with relevant long-run elasticity below unity (0.29). The diesel price has a negative effect (−0.10), while the diesel fleet has a positive one (0.28). Both have almost the same magnitude with relative long-run elasticities below unity. In other words, a 10% increase in GDP will lead to a 3% increase in diesel demand, whereas a 10% increase in the prices of diesel price or fleet will lead to a 1% increase in diesel demand (almost half the GDP effect). Thus, diesel demand appears to be inelastic to variations of all its determining factors. The above results are in line with those reported in other countries (e.g. Sterner, 2006; Bakhat *et al.*, 2013; Dunkerlay and Hoch (1987). However, in contrast to similar studies (e.g. Polemis, 2006), the cross-price elasticity of diesel demand (RPGASOL), although negative, is highly statistically significant in the long-run with an estimated value of −0.47. This means that petrol and diesel cannot be regarded as substitutes as expected by the theory because a driver of a petrol-engine vehicle must bear a significantly high switching cost to use a diesel car and vice versa. The absence of close substitutes such as petrol, natural gas, LPG and hydrogen that could have significant impact on the environment (i.e. combating CO_2 emissions) may support the argument that scope for energy switching in the road sector is still limited (Polemis, 2006).

Variable	DCON			
	Coefficient	SD	*t*-Statistic	*P* value
Constant	3.45***	1.13	3.05	0.00
GDP	0.29***	0.11	2.61	0.01
DIESELPRICE	−0.10**	0.05	−2.00	0.05
RPGASOL	−0.47***	0.10	−4.54	0.00
DIESELFLEET	0.28***	0.04	6.10	0.00
Diagnostics				
Adjusted R^2	0.92			
Durbin–Watson statistic	1.46			
LM test	1.84 [0.118]			
White test	2.34 [0.130]			
J. Bera	1.40 [0.49]			
ARCH test	2.63 [0.125]			
Chow-test	0.58–5.24			
Breakpoints 1992, 2003	[0.71]–[0.000]			

Table 1. Long run-estimations
Significant difference at **5% level, ***1% level.
Notes: Numbers in square brackets denote *P* values.

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Variable	Δ(DCON)			
	Coefficient	SE	*t*-Statistic	*P* value
Δ(GDP)	0.59**	0.28	2.12	0.042
Δ(DPRICE)	−0.23**	0.10	−2.33	0.026
Δ(DFLEET)	−0.06	0.21	−0.27	0.786
ECM_RESID(-1)	−0.52***	0.14	−3.73	0.001
Diagnostics				
Adjusted R^2	0.35			
Durbin–Watson statistic	1.47			
LM test	2.3 [0.119]			
White test	1.36 [0.256]			
J. Bera	9.98 [0.007]			
ARCH test	0.54 [0.468]			

Table 2. Estimated short-run elasticities
Significant difference at **5% level, ***1% level.
Notes: petrol price was not statistically significant (ΔRPGASOL) and therefore was not incorporated in the short-run model. Numbers in square brackets are *P* values.

Short-Run Estimations

Having estimated the long-run elasticities, we now focus on short-run estimations. It is evident from Table 2 that all the coefficients of the variables relating to diesel demand are in alignment with the theory and are statistically significant, except for the fleet of diesel vehicles, which is not (in the short-run).[6]

More specifically, short-run income elasticity is below unity and is estimated to be 0.59, implying that a 1% increase in per-capita GDP will increase diesel demand at a much lower rate (0.59%). The short-run elasticity with respect to its own price is also estimated to be less than unity (0.23), implying a low-level response of diesel demand to its own price fluctuations, highlighting the difficulty of consumers in substituting diesel with other energy products (petrol, LPG, natural gas, hydrogen, fuel cells, etc.). The short-run elasticities of both statistically significant variables are lower (at least slightly lower for GDP) than the long-run elasticities, satisfying the LeChatelier principle (Milgrom and Roberts, 1996).

The error correction term $(ECT)_{t-1}$ is strongly significant (t statistic −3,73 and $P = 0.0008$) with an adjustment coefficient of −0.52, implying that, off the long-run demand curve, diesel consumption adjusts towards its long-run level with about 52% of this adjustment taking place within the first year. The diesel dynamic demand function appears to be well behaved to the diagnostic tests, including the adjusted R^2 (35%), the serial correlation (LM test), the autoregressive conditional heteroscedasticity test (ARCH test) and the white for heteroscedasticity test. In other words, the estimated statistics support the structural stability of the estimated regression (diesel demand) for the examined period used in the empirical analysis.

Forecasting

Having calculated and tested our demand estimation model, we enter the area of forecasting, aiming to meet our end goal, which comprises two consecutive steps. The first step is estimating the future demand of diesel oil. Secondly, we proceed to apply the policy scenarios, regarding possible regulatory mandates of biodiesel blending, on future diesel oil estimates. Thus, this process will enable us to formulate basic views of how local biodiesel demand could potentially develop.

[6]Similarly to other empirical studies (e.g. Polemis, 2006) the effect of petrol prices on short-run diesel demand is not statistically significant and therefore it is not reported.

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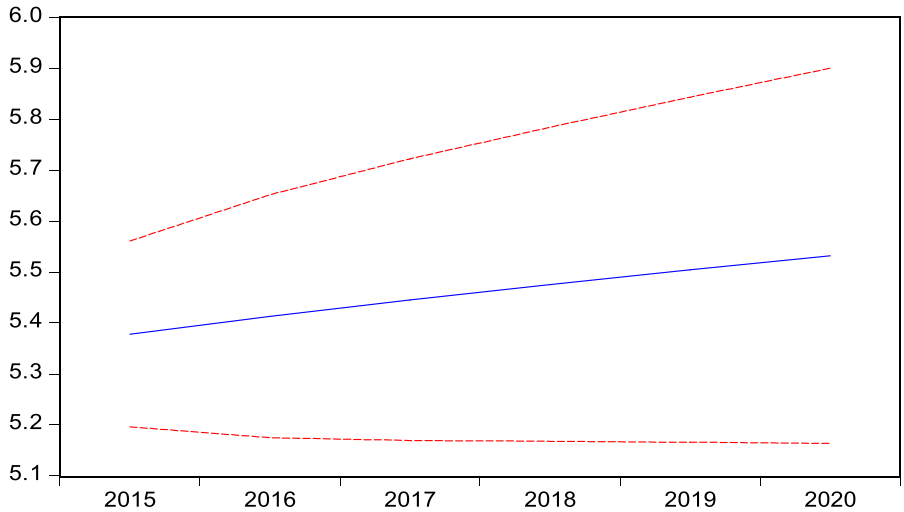

Notes: On the verticals axis is the forecasted diesel consumption per capita in logarithmic scale. The dotted red curves represent forecasts with ± 2 standard errors.

Figure 1. Short-term forecast of diesel oil demand (ARIMA model)*Notes*: On *y*-axis is the forecasted per-capita diesel consumption (log scale). The dotted red curves represent forecasts ±2SE. [Colour figure can be viewed at wileyonlinelibrary.com]

The energy forecast models are grouped under two major classes: the computable general equilibrium (CGE) models, which are a class of economic models that use actual economic data to estimate how an economy might react to changes in policy, technology or other external factors, and the partial equilibrium models (PEMs), which consider only a part of the market, other things being equal, to attain equilibrium. In our case, we are referring to a PEM because our study focuses on the demand of a single energy commodity.

Diesel Demand

Our forecasts will stretch from 2015 to 2030. It is not recommended to extend further in the future, because the longer the forecast, the lesser its probability to occur.[7] We apply two forecasting approaches: (i) the first one is rather short-term, extending from 2015 to 2020 and following the Box–Jenkins or ARIMA (autoregressive integrated moving average) methodology.[8]

This method, which is widely used for the analysis of time series, conducts forecasts for a time series Y_t based on its past values only, without any other structural information. For example, no information regarding which determinant variables have an impact on time series Y_t is required (Tsionas, 2009). Since our series (DCON) is not stationary on levels, we take the first differences and formulate a new series as follows:

$$\Delta(\mathrm{DCON})_t = \mathrm{DCON}_t - \mathrm{DCON}_{t-1} \tag{2}$$

We then apply the ARIMA (1, 1, 1) model on the new series, which takes the following expression:

$$\Delta(\mathrm{DCON})_t = b_o + b_1\Delta(\mathrm{DCON}_{t-1}) + e_t + a_1 e_{t-1} \tag{3}$$

where b_1 is the autoregressive coefficient, a_1 is the moving average coefficient and e_t are the error terms (generally assumed to be independent, identically distributed variables sampled from a normal distribution with zero mean). In general, the ARIMA models are considered appropriate for short-term predictions and this is the main reason for applying such a technique for our forecast up to 2020 (Figure 1).[9]

[7]Chatfield C. 2001. Time-Series Forecasting. Chapman & Hall/CRC: FL, USA: 7.
[8]In time series analysis, the Box–Jenkins methodology applies autoregressive moving average (ARMA or ARIMA) models to find the best fit of a time series model to past values of a time series.
[9]The credibility statistics of ARIMA models are available upon request.

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As mentioned before, our dependent variable –diesel consumption – is the natural logarithm (*ln*) of diesel consumption measured in thousand tonnes per capita (divided by 10^6 to limit the digits of the numbers). We continue with the conversion of the forecasted logarithms to absolute numbers aiming to estimate the future demand of diesel oil in its basic globally measure, i.e. thousand tonnes or kT.

The second approach, which is more long-term as it extends from 2015 to 2030, follows the methodology of simple linear models and is recommended if values of the determinant variables/factors are known or can be predicted (Tsionas, 2009). The greatest and most crucial challenge of this approach is prediction of the determinant variables. To this end, we have developed three scenarios. First, we focus on one reference scenario (RS), which is the most probable, and then, in line with the basics of sensitivity analysis (Saltelli, 2002), we design two alternative scenarios of equal deviation from the reference scenario: (i) the over performance scenario (OPS) and (ii) the under performance scenario (UPS).

The predictions for the evolution of GDP, diesel price and diesel fleet differ in all three scenarios. Their logic will be detailed later in the paper. The only factor remaining unchanged throughout the scenarios, indirectly affecting two of the three determinant variables and the dependable variable as well, is population. Note that GDP, diesel fleet and diesel consumption are variables per capita. We chose not to differentiate the population evolution projections, since on the one hand no tangible studies with more than one likely-to-occur scenario could be retrieved and on the other hand it is a far more complex issue that expands beyond economic implications and is associated with social and cultural developments of indeterminant impact. Population evolution is derived from the Global Forecasting Model of the University of Denver.[10]

Regarding the evolution of GDP, our RS considers the most recent release of the OECD.[11] From 2016 onwards, the economy is expected to grow continuously, more intensively in the first 3 years (5% per year) and then gradually less intensively but still significantly (3% for a period of 10 years). The basic assumption of the two scenarios is that the economy of Greece performs better and worse, respectively, compared to OECD forecasts. To achieve symmetry between the two scenarios, we applied an equal – in absolute value – deviation rate from the reference one. Thus, in the OPS, the evolution of GDP from 2015 to 2030 accelerates by 50% each year, while in the UPS it decelerates by 50%. GDP progress in all the scenarios is the driver that also determines the course of the other two explanatory variables (diesel fleet and diesel price).

With regard to diesel fleet, in the RS, we assume that the speed of replacing petrol cars with diesel that we have witnessed during previous years of the current economic downturn and following lifting of the diesel ban in 2011 will keep up. During 2011–2014, the average annual rate of diesel fleet growth has been 10% which we maintain until 2030, while the average rate of petrol fleet decrease has been 1.25%. We assume that this rate will increase slightly to 2% until 2030, given that the economy is expected to start growing again from 2016, so that people will have a greater desire to replace their petrol vehicles. By 2030, the diesel vehicle market share will have risen from 8% in 2014 to 35%, much closer to the current European Union (EU) average of 53% (according to ACEA). The total fleet will be 8273 million cars, 3% more than in 2014. In the OPS, we assume that replacement rates will be even higher, with the diesel fleet growing by 15% for the first 6 years and then gradually balancing to 10% annually, whereas the gasoline fleet will shrink by 3% annually. In 2030, the diesel market share will be 48%, very close to the EU current average, while the total fleet will be 8% more than in 2014. Finally, in the UPS, replacement rates will be approximately half that of the RS, with a 5% increase of the diesel fleet and 1% reduction of the petrol fleet per year. This will give a diesel market share of 18% and total fleet approximately 4% less than at the beginning.

Predicting price variations can be a complicated exercise with great uncertainties. This is particularly so when dealing with fully commercialized commodities such as fuels, the prices of which are influenced in multiple manners and in various fields such as at physical markets, exchange houses, through over-the-counter transactions, due to supply and demand curves, speculation, arbitrage, political pressure, technological innovation, depletion of oil fields and competition from substitutes. Very few forecast schemes for the prices of petroleum products exist, such as the Platts published daily under their Forward Curves assessment platform, and they

[10]http://www.ifs.du.edu
[11]https://data.oecd.org/gdp/gdp-long-term-forecast.htm

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Year	*ln* of per-capita diesel demand	Diesel demand (kT)	Diesel demand compared to previous year
2014	5.34	2317	
2015	5.38	2410	4%
2016	5.41	2482	3%
2017	5.45	2559	3%
2018	5.48	2630	3%
2019	5.50	2702	3%
2020	5.53	2769	2%

Table 3. Forecast of diesel demand and annual change until 2020

are rather short- or medium-term as they extend up to 36 months. We therefore simplify the process by adopting the following approach. Firstly, we decompose the end price (retail price) of diesel oil. It consists of tax and commodity value. Then, we decompose the taxation component, which comprises VAT and Excise Duty.[12] Their cost contribution is known; for example excise duty on diesel oil in 2014 was €330 per 1000 litres and VAT was 23%. Removing taxation from the end price leads to the commodity price. The task now is to predict the evolution of taxation and commodity prices. The commodity of interest is diesel oil, which is one of the many distillates of crude oil. Because long-run projections for petroleum products are not available, we make the assumption that diesel oil prices will follow those of crude oil in the long run. According to literature and historical data, this is a reasonable assumption.

Therefore, we will parallel our predictions for the evolution of the commodity value of diesel oil with the latest forecast of the World Bank for crude oil,[13] applying the same to all three scenarios as local economic developments are highly unlikely to influence the global prices of crude oil. After completing the curve for the commodity value of diesel, we enter the area of tax policy forecasts. Given that historically governments tend to increase taxes when the economy is under-performing but maintain them under normal or better performance, we formulate the following assumptions. In the RS, the VAT of 23% in 2014 will increase to 24% in 2016 (as already determined) and remain at this level throughout the period. The average level of VAT in the EU is currently 21.5%. Excise duty, which is €330 per 1000 litres in 2014, will increase to €410 in 2017 (adopted legislation) and will gradually reach €438 per 1000 litres by 2030, i.e. the current EU average. Note that the current excise duty of €330 is the minimum allowed in accordance with the Energy Directive (Council Directive 2003/96/EC). In the OPS, VAT will increase to 24% in 2016 (adopted legislation) and gradually decrease to 21.5% (EU average). Excise duty will rise to €410 in 2017 (adopted legislation) and remain at this level. In the UPS, both VAT and excise duty will gradually increase to the highest in the EU as per current levels, i.e. VAT will rise to 27% (as currently in Hungary) and excise duty will reach €623 per 1000 litres (as currently in Sweden).[14]

Finally, we perform the opposite process, adding up the taxation elements and commodity values, to compose the diesel oil end price per scenario. At this point, all our covariates in all the three scenarios have been calculated. We continue with feeding them in serially into our linear model (of the long-run regression) and produce the results for the evolution of diesel oil demand under each scenario. Similarly to the previous approach (ARIMA model), we then reverse the natural logarithms of per-capita diesel consumption into its basic unit of measure (thousand tonnes).

Naturally, there are significant differences between the three scenarios we have studied (Table 3; Figure 2). As a general remark, in the less optimistic scenario (under-performance) diesel demand will grow by approximately 34% by 2030, in the reference scenario by 224% and in the more optimistic one by 297% (See Table 4).

[12]VAT is imposed on the sum of commodity cost and Excise Duty.
[13]http://www.worldbank.org/en/research/commodity-markets
[14]Fuel excise duty and VAT data have been derived from EXCISE DUTY TABLES, European Commission (2016), http://ec.europa.eu/taxation_customs/index_en.htm

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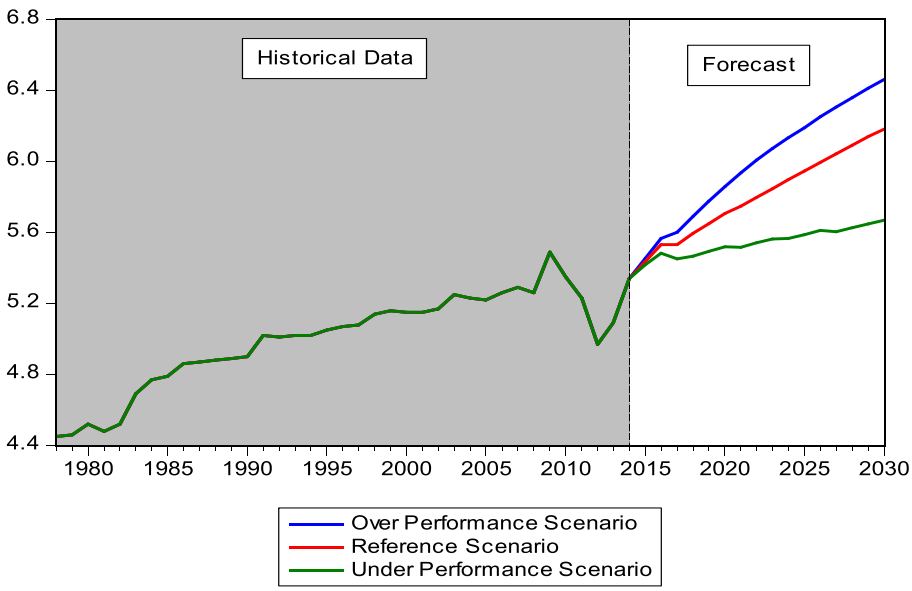

Figure 2. Diesel oil demand 1980–2030 [Colour figure can be viewed at wileyonlinelibrary.com]

	UPS			RS			OPS		
YEAR	GDP	Diesel fleet	Diesel price	GDP	Diesel fleet	Diesel price	GDP	Diesel fleet	Diesel price
2014	−1	9	−4	−1	9	−4	−1	9	−4
2015	0	5	−33	0	10	−33	0	15	−33
2016	3	5	−8	5	10	−8	5	15	−8
2017	3	5	23	5	10	23	8	15	23
2018	2	5	6	5	10	2	7	15	2
2019	2	5	2	4	10	2	6	15	2
2020	2	5	2	4	10	2	5	15	2
2021	2	5	10	3	10	5	5	14	1
2022	2	5	2	3	10	2	5	13	2
2023	2	5	2	3	10	2	5	12	2
2024	1	5	9	3	10	2	4	11	2
2025	1	5	2	3	10	2	4	10	2
2026	1	5	2	3	10	2	4	10	0
2027	1	5	11	3	10	2	4	10	3
2028	1	5	2	3	10	3	4	10	3
2029	1	5	2	3	10	3	4	10	3
2030	1	5	2	2	10	3	4	10	3

Table 4. Forecasted values of diesel oil demand under the three alternative scenarios (%)
UPS, underperformance scenario; RS, reference scenario; OPS, overperformance scenario. = = .

Biodiesel Demand

In the second and last part of our forecasting process we aim to apply alternative policy scenarios regarding the biodiesel blending rate on diesel demand projections to outline potential biodiesel demand in Greece for the next 15 years.[15]

[15]As already stated, the current blending rate – valid from 2013 – has been regulated at 7%. This blended fuel is also called B7. Hereafter, the 7% blending rate is our base case scenario (Tables A1 and A2).

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Forecasting the Biodiesel demand in Greece

According to the aforementioned study, the most probable blending rate to adopt would be 10%, with diesel fuel B10. However, there are other scenarios suggesting 20 and 30% blending rates (B20 and B30). We consider the 10% scenario as the most probable one in terms of feasibility in Greece, with the fewest technical and economic constraints to overcome, and a blending rate over 15% seems highly unlikely. Given that biodiesel production in Greece is mainly energy crop-based and a 7% cap on renewable energy for road transport deriving from energy crops has been legislated, the biodiesel blending rate, without any significant restructuring of the market, could increase up to approximately 15%. The three scenarios thus consist of the base case ratio of 7%, the most probable case ratio of 10% and the maximum case ratio of 15%.

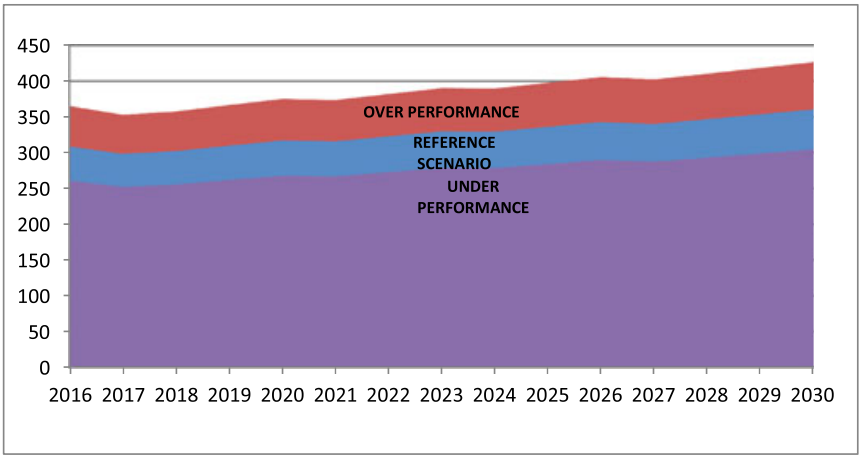
At the base case, the 7% ratio is maintained up to 2030, whereas at the most probable case, we assume that the 10% ratio is adopted from 2018 onwards. The blending ratio is not going to change for 2016 and we assume the same for 2017, as no formal initiatives have yet been made public. At the maximum case ratio, we assume that before adopting the 15% ratio, there will be an adjustment period of 10% between 2018 and 2020. The aforementioned rationale of the alternative biodiesel policy scenarios is then applied to the three diesel demand projections, i.e. at the under-performance, reference and over-performance scenarios.

In Figures 3–8, we illustrate each biodiesel blending ratio case versus the three alternative performance scenarios of diesel demand. The reverse illustration is also of interest, i.e. each diesel demand performance scenario versus the three alternative blending ratio cases.

Conclusions and Policy Implications

In this study we attempt to examine the possible spillovers generated by the use of biofuels on achieving sustainability. Therefore, we estimate a simple econometric model of diesel demand in Greece over the period 1978–2014. The estimated elasticities were used in the second stage to provide forecasts on biodiesel consumption within the next 15 years on the basis of three alternative policy scenarios.

Our examination of diesel demand showed clearly that automotive diesel oil demand increased as long as the country's GDP was growing, from 1978 to 2008; from 2008 to 2011 it faced a downfall due to the economic crisis and as of 2011 because lifting of the ban on diesel led to a dramatic increase. After identifying potential factors determining diesel demand (GDP, diesel price, diesel fleet), we thoroughly tested and analysed them and the interactions between them (stationarity, co-integration, long-term regression, short-term regression) following the



Notes: Values of vertical axis are the projected biodiesel demand volumes in thousand cubic meters or million liters.

Figure 3. Forecasts with base case blending ratio of 7%, 2016–2030*Notes*: values on *y*-axis are the projected biodiesel demand volumes in thousand cubic metres or million litres. [Colour figure can be viewed at wileyonlinelibrary.com]

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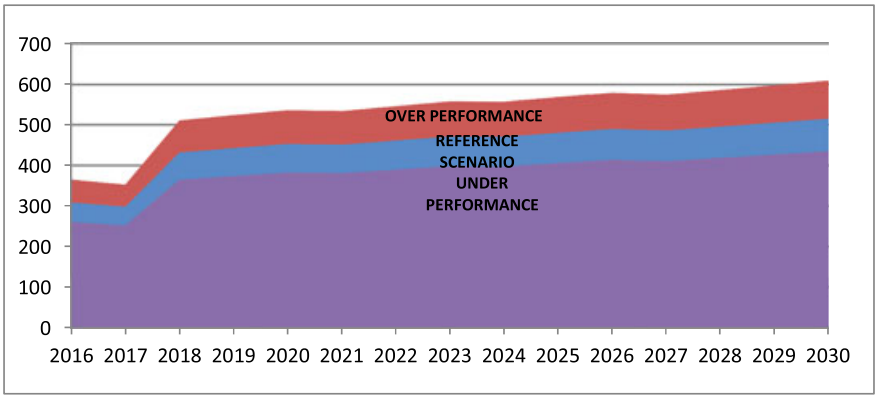
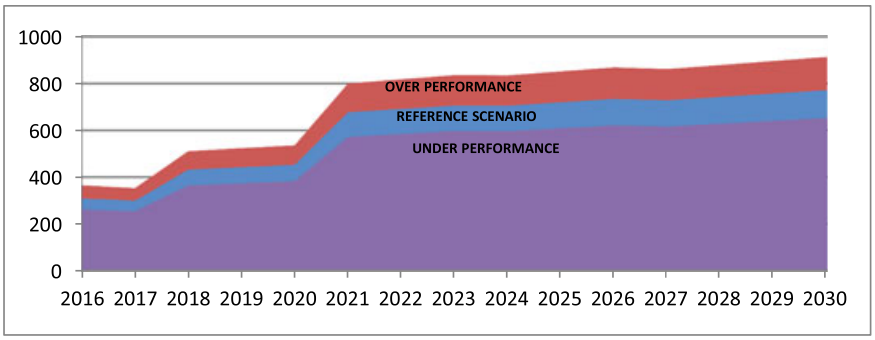


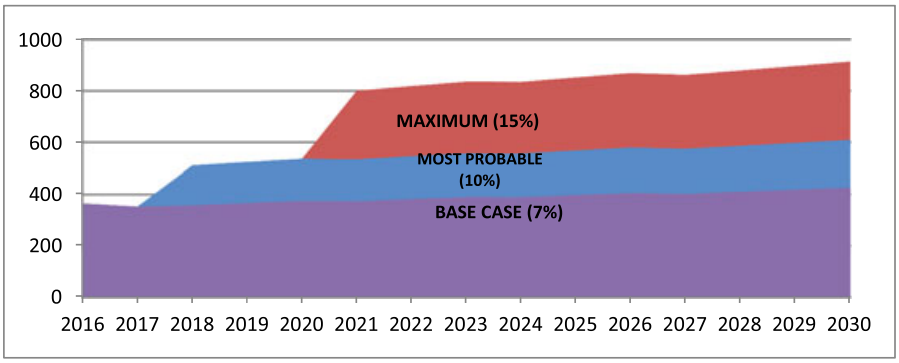
Notes: Values of vertical axis are the projected biodiesel demand volumes in thousand cubic meters or million liters.

Figure 4. Forecasts with most probable case blending ratio of 10%, 2016–2030*Notes*: values on *y*-axis are the projected biodiesel demand volumes in thousand cubic metres or million litres. [Colour figure can be viewed at wileyonlinelibrary.com]



Notes: Values of vertical axis are the projected biodiesel demand volumes in thousand cubic meters or million liters.

Figure 5. Forecasts with maximum case blending ratio of 15%, 2016–2030*Notes*: values on *y*-axis are the projected biodiesel demand volumes in thousand cubic metres or million litres. [Colour figure can be viewed at wileyonlinelibrary.com]



Notes: Values of vertical axis are the projected biodiesel demand volumes in thousand cubic meters or million liters.

Figure 6. Forecasted biodiesel demand at the UPS, 2016–2030*Notes*: values on *y*-axis are the projected biodiesel demand volumes in thousand cubic metres or million litres. [Colour figure can be viewed at wileyonlinelibrary.com]

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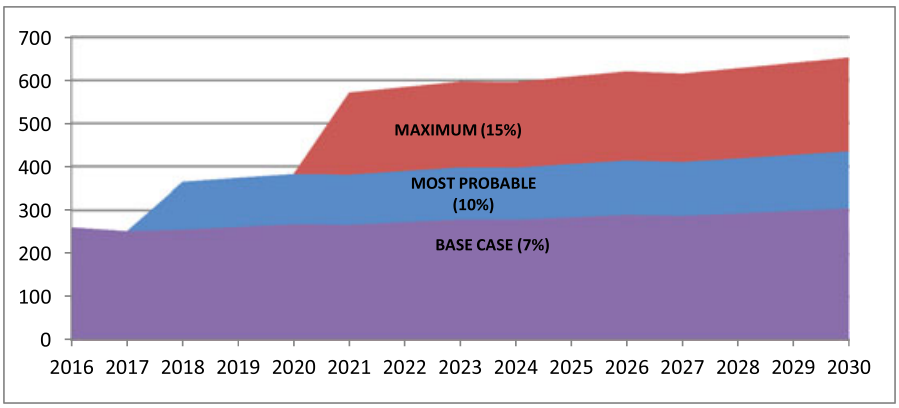
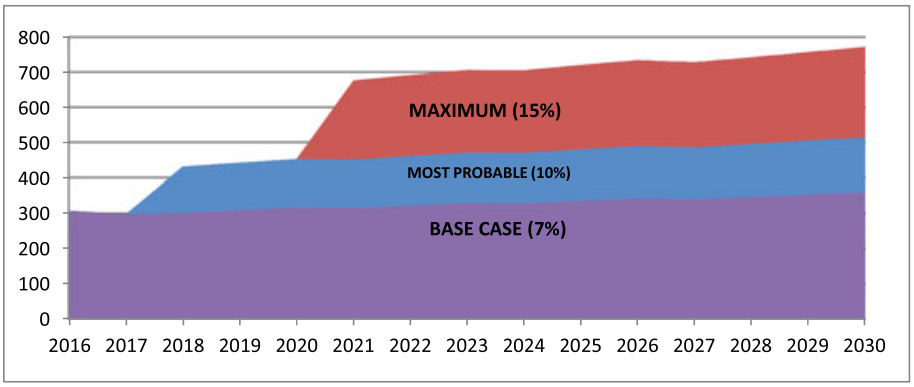


Notes: Values of vertical axis are the projected biodiesel demand volumes in thousand cubic meters or million liters.

Figure 7. Forecasted biodiesel demand at the RS, 2016–2030*Notes*: values on *y*-axis are the projected biodiesel demand volumes in thousand cubic metres or million litres. [Colour figure can be viewed at wileyonlinelibrary.com]



Notes: Values of vertical axis are the projected biodiesel demand volumes in thousand cubic meters or million liters.

Figure 8. Forecasted biodiesel demand at the OPS, 2016–2030*Notes*: values on *y*-axis are the projected biodiesel demand volumes in thousand cubic metres or million litres. [Colour figure can be viewed at wileyonlinelibrary.com]

methodology of other researchers and concluded by identifying statistically significant elasticities that may specify the demand of our dependent variable (automotive diesel oil demand).

In the next step, we forecasted using short-term and long-term elasticities. We initially tried to forecast the short term – up to 2020 – diesel demand and therefore the related biodiesel demand, using only the ARIMA methodology. The results showed that compared to 2014, diesel oil demand and subsequently biodiesel demand will increase by 20% by 2020. In the second approach, and extending up to 2030,we applied the methodology of simple linear models, using the model we had previously specified. Due to the level of uncertainty in such approach,we applied a sensitivity analysis, formulating three possible scenarios: the reference scenario, the under-performance scenario and the over-performance scenario.

The results indicate that by 2030, in the worst case scenario diesel demand will grow by approximately one-third, in the basic case it will double and in the best case it will triple. Note that even under the worst case scenario, with the lowest GDP growth rates, the highest diesel oil prices and the highest taxation rates (which contribute significantly to the final diesel price), a significant diesel demand growth rate is expected, and this should not to be overlooked the market stakeholders. Finally and after forecasting the evolution of diesel oil demand, we attempt to project the relevant biodiesel demand with reference to alternative policy scenarios regarding biodiesel blending ratio mandate. We identify three alternative blending ratios, the base case being the current one (7%), the most

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probable (10%) being derived from a comprehensive review of the EU biofuels market commissioned by the Directorate Transport and Energy (DG - TREN), and the maximum (15%) being a combination of the latter review's alternative scenario and the maximum allowed blending ratio according to the 7% cap on renewable energy for road transport deriving from energy crops and the current biodiesel market structure of Greece. The results are variable, as multiple scenarios are implemented. Outlining the overall landscape, the combination of the worst performance scenario with the lowest blending ratio provides a doubling of the 2015 biodiesel market by 2030, i.e. approximately 280 000 thousand litres, whereas the combination of the best performance scenario with the maximum blending ratio leads to a six-fold greater biodiesel market by 2030, i.e. approximately 900 000 thousand litres.

These results could be important for policy makers, academic researchers and government officials. More specifically, they call for the need to strengthen the effectiveness of energy-generating agencies by promoting the use of biofuels to drastically tackle with environmental degradation. The overall findings suggest that the extensive use of biofuels such as biodiesel might stimulate economic growth. Intuitively, improvements in the oil industry are an important prerequisite for an improved Greek economy. It is therefore necessary to ensure secure, reliable, efficient, clean and sustainable biodiesel penetration in the country. Hence, policy makers should put in place any necessary policies that could restructure the diesel supply industry. Restructuring could be done, if needed, by adopting retail competition policies that advocate that more players enter the biodiesel supply industry, resulting in more biodiesel being supplied, while keeping diesel prices low.

Lastly, it would be wrong to claim that the topic of biofuels has been exhaustively studied, as it is a complex, continuously changing and controversial subject. Future studies could potentially include a different methodology regarding forecasting such as a Monte Carlo approach, an investigation of second-generation (advanced) biofuels in Greece, a deeper analysis of local market distortions, a thorough research of the potential of bioethanol, and an assessment of the potential of marine biofuels.

Acknowledgments

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Appendix

		Max. vehicle availability (share of fleet)	Cost (vehicles)	Cost (fuels)	Need for protection grade?
Increase blending limits for large share of vehicles					
2	Blending limit for diesel from B7 to B10	Cars: 20% HDV: 85%	Cars: low/medium Trucks: low	Low	Yes
2A	Blending limit for diesel from B7 to B10 (15% cars in 2012)	Cars: 20%	Low/medium	Low	Yes
2B	Blending limit for diesel from B7 to B10 (HDV 85% in 2012)	HDV: 85%	Low	Low	Possibly not
8	25% market share of B30 for trucks	Trucks and buses: 25%	Low	Low	NA
9	10% market share of B100 for trucks	Trucks and buses: 10%	Medium	Low	NA
Increase biofuels use in non-road modes					
15	Increased use of B20 in inland shipping (10%)	50%	Low	Low	Yes
16	Increased use of B20 in trains (10%)	100%	Low	Low	Yes

Table A1. Overview of the assessment of biodiesel blending options (expected physical limitations)
Source: Kampman *et al.* (2013).

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	Marketing issues (consumers)	Potential for further decarbonization (post-2020)	Main constraints	EU policy efforts needed
Increase blending limits for large share of vehicles				
Blending limit for diesel from B7 to B10 (15% cars, HDV 40%)	Consumers may prefer B7. Price advantage B10 recommended	Technical: +	Acceptance of car OEMs, consumer demand, availability of sustainable feedstock	Negotiate implementation. B10 as reference fuel for pollutant emission legislation (HD probably earlier than cars)
Blending limit for diesel from B7 to B10 (15% cars)	Consumers may prefer B7. Price advantage B10 recommended	Technical: 0	Acceptance of car OEMs, consumer demand, availability of sustainable feedstock	Negotiate implementation. B10 as reference fuel for pollutant emission legislation
Blending limit for diesel from B7 to B10 (HDV 40%)	Consumers may prefer B7. Price advantage B10 recommended	Technical: +	Acceptance of car OEMs, consumer demand, availability of sustainable feedstock	Negotiate implementation. B10 as reference fuel for pollutant emission legislation
High blends in niches (captive fleets)				
25% market share of B30 for trucks	Users may prefer standard diesel B7 or B10. Price advantage B30 recommended (on energy basis)	Technical: +	Availability of sustainable feedstock, consumer demand (incl. Cost and environmental perception), sufficient number of type approval Euro VI and Euro VII B30 trucks	Coordinate agreement with vehicle and oil industry about vehicle availability and fuel price compared to other fuels, decide on ILUC
10% market share of B100 for trucks	Price of B100 should be lower or comparable to standard diesel. Uncertainty about fuel flexibility (B100 and B10 compatible)	Technical: 0	Availability of sustainable feedstock, consumer demand (incl. Cost and environmental perception), sufficient number of type approval Euro VI and Euro VII B100 trucks	Coordinate agreement with vehicle and oil industry about vehicle and fuel availability and fuel price compared to other fuels, decide on ILUC
Increase biofuels use in non-road modes				
Increased use of B20 in inland shipping (10%)	Hesitation with biocomponents and associated operational risks. Fuel price must be competitive on MJ basis	Technical: +	Availability of sustainable feedstock, consumer demand (i.e. cost and environmental perception), technical issues with storage and auxiliary systems	Decide on ILUC. Organize competitive price for B20
Increased use of B20 in trains (10%)	Not very positive image. Fuel price must be competitive on MJ basis	Technical: +	Availability of sustainable feedstock, consumer demand (i.e. cost and environmental perception), technical issues with storage and auxiliary systems	Decide on ILUC. Organize competitive price for B20

Table A2. Overview of the assessment of biodiesel blending options
Source: Kampman *et al*. (2013).

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