Iberian distribution planning of fuels – the impact of biofuel price quotations in decision-making

Galp Case Study

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Abstract - Barack Obama, the 44th President of the United States of America, stated that *Climate Change is no longer some far-off problem; it is happening here, it is happening now*. Biofuels appear as renewable energy sources, with the potential to replace fossil fuels and might be part of the solution. Concerning the Iberian Peninsula, biofuels like biodiesel (FAME) and bioethanol are blended with either diesel or gasoline. Due to its relevance, the biofuel's quotation is an important factor to consider when designing and planning the downstream supply network. Bearing that thought, this dissertation has the goal to study the Iberian fuel distribution system, taking the perspective of one Iberian player - Galp - and looking into the specific problem of biofuels quotations and its impact in tactical and operational level of Galp's planning. For that purpose, different scenarios are built and tested in Galp's downstream optimisation model. The current model involves dozens of parameters such as transportation costs or energetic targets. Due to the obvious complexity of studying all the input parameters and their relationship with the biofuels quotations, it was decided to study several international reference prices - the exchange rate between dollar and euro and MTBE, methanol, gasoline and diesel quotations alongside with FAME and ethanol reference prices. Following the proposed methodology, the key results indicate that FAME's quotation has a larger impact in the downstream network compared to the Ethanol's quotations. This impact can be understood from different perspectives. Either an impact in the supply assignment or an impact in the downstream supply costs.

Keywords: Downstream Planning; Biodiesel ; Bioethanol; Oil distribution; Fuel Prices' Quotations.

1. Introduction

1.1 – Contextualization

Climate change is one of the most complex issues facing us today. It involves many dimensions - science, economics, society, politics and moral and ethical questions - and is a global problem, felt on local scales, that will be around for decades and centuries to come (Speth, 2009).

In 1979, scientists from 50 nations gathered in Geneva for the First World Climate Conference and acknowledged that alarming trends for climate change made it urgently necessary to act. Since then, analogous alarms have been made through Rio Summit (1992), the Kyoto Protocol (signed in 1997) and the Paris Agreement (2015), as well as other global assemblies and scientist's explicit warnings of insufficient progress (Ripple et al., 2017). Exacerbating this worldwide issue, in its 5th Assessment Report (IPCC, 2014), the Intergovernmental Panel on Climate Change (IPCC), a group of 1,300 independent scientific experts from countries all over the world under the auspices of the United Nations, concluded there is a more than 95 percent probability that human activities over the past 50 years have warmed our planet (NASA, 2020a) (IPCC, 2014) (Oreskes, 2004). Carbon dioxide, the heat-trapping greenhouse gas that has driven recent global warming, lingers in the atmosphere for hundreds of years, and the planet (especially the oceans) takes a while to respond to warming (NASA, 2020b). The carbon dioxide is released through human activities (e.g. deforestation and burning of fossil fuels), as well as natural processes such as respiration and volcanic eruptions. Furthermore, considering global fossil fuel combustion and industrial processes, such emissions have seen dramatic inflation in usage. Recently, in 2018, the world saw about 36.57 billion tons of carbon dioxide emitted (Statista, 2019).

European legislation on Renewable Energy Sources (RES) promotion represents a pioneering and ambitious attempt to transform energy systems in the face of climate change. The European Union's renewable energy policy has been in the making for decades. Its history comprised small and incremental steps dating back to the 1970s (Nilsson, 2011). From the late 1990s onwards, however, in the wake of the single market agenda and the establishment of an international climate change regime, more substantial policy developments were put into motion. (Solorio & Jörgens, 2017).

EU began implementing biofuel-related targets in 2003 with Directive 2003/30/EC. This first Biofuel Directive stated that *Member States should ensure that a minimum proportion of biofuels and other renewable fuels is placed on their markets, and, to that effect, shall set national indicative targets*. Therefore, a biofuel penetration target of 2% by the end of 2005 and 5.75% by the end of 2010 were indicated (both calculated on basis of energy content) European Parliament, 2003.

Over the following years, the EU directives have evolved to fulfil more challenging environmental targets. For instance, the latest Renewable Energy Directive (RED) incorporates an overall target for 2030 of at least 32 % of energy from renewable sources (European Parliament, 2018).

1.2 – Case-Study Introduction

Portugal, as a European Union's member, had to transpose the European legislation and directives in its national law. Consequently, companies within the oil industry were forced to readjust their businesses. In the beginning, those changes were mainly to meet legal requirements, although, over the years, apart from this legal constraint, biofuels became crucial in what concerns competitive leverage among rivals. This research will analyse a real and UpToDate case-study of the largest Portuguese oil company, Galp, focusing particularly on the importance and impact of biofuels in the Iberian supply planning and optimisation activities.

The downstream planning of fuel distribution is a complex problem since the number of demand locations escalates when including the primary and secondary segments. In a competitive environment of high-level of complexity, the regular search for efficiency is immense. Within this planning and optimisation context, efficiency should be portrayed as optimised costs. On this basis, this dissertation aims to analyse to impact of the biofuels' prices in the designed network of supply.

2. International Quotations: Argus and Platts

The Argus Biofuels service is a daily report that provides key international insights into the biodiesel, ethanol and feedstock markets. It is provided key prices for freight, spot prices, physical forward prices and spreads to navigate this growing international marketplace. All assessments are compliant with the Renewable Energy Directives for sustainable biofuels (Argus, 2020). Further, Platts quotations' service provides insight within the petroleum-based products. Put differently, it gives daily reference prices for products like diesel or gasoline (SP Global, 2020). Oil companies within the Iberian Peninsula may utilise these international quotations of the biofuels and petroleum markets, Argus and Platts, when trading and negotiating with each other the acquisition or selling of oil products (e.g. in refineries). Each company has its own mathematical formula of selling fuels and biofuels, although the roots are the Argus and Platts reference prices.

3. A brief context of Galp

3.1 – Galp's Downstream Planning of Iberian Supply

Considering the Iberian Fuel distribution system, Galp is the biggest player in Portugal and an important player in Spain. Therefore, in order to be successful, Galp needs not merely to play by the rules of this sector - either legal directives in each country, environmental legislation, technical and science *status quo* - but also to meet customers' expectations.

The downstream planning of fuel distribution is a complex problem, since the number of demand locations escalates when including the primary (refinery to depot) and secondary (depot to service station) segments (see figure 1).

The complexity is also related with the fact that different products are present, with different supply locations and supply constraints. When several companies are present in the supply region, in order to remain competitive, each company has to carefully include all the related information in the planning procedure, so as to take the most informed and competitive decisions.

The Iberian Peninsula comprehends two different paradigms for Galp. On the Portuguese side, Galp fully owns and explores all refineries, namely Matosinhos

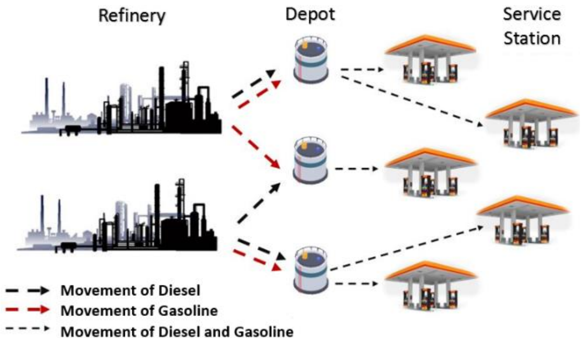

***Figure 1** – Overview of Petroleum Downstream network.*

Refinery and Sines Refinery. Although, on the other side of the border, different Galp's competitors own and explore the 8 Spanish refineries - Repsol possesses 5, Cepsa has 2 and BP explores 1. Further, the logistics infrastructures are different in both countries. In Portugal, there is 1 oil pipeline (operated by CLC) whereas in Spain there is a complex network of pipelines (operated by CLH) connecting refineries to depots - in both sides of the border, whether pipelines are not available, the connections are operated by truck.

Figure 2 describes the Portuguese situation, illustrating both refineries, identifying the different players in each depot and the only oil pipeline. Diversely, figure 3 illustrates the complex Spanish pipeline network, the 8 refineries and its explorer and the main available depots (including 2 controlled by Galp, notwithstanding it also operates in CLH, Esergui and Decal depots).

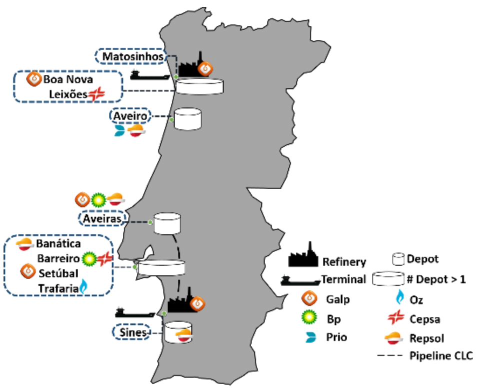

***Figure 2** – Overview of Portuguese Petroleum Downstream Logistics: From refineries to depots.*

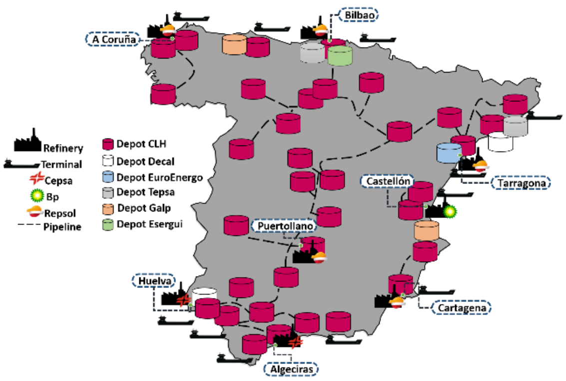

***Figure 3** – Overview of Spanish Petroleum Downstream Logistics: From refineries to depots.*

The primary aim of Galp's downstream planning is to maximise results (margins) considering product supply and logistics costs. Understanding and adjusting the areas of influence of each refinery - which refinery supply each depot - and the areas of influence of each depot - which depot supply each service station - is crucial to accomplish such goal. Currently, this downstream planning is accomplished through an optimisation model developed through GRTMPS software.

Regarding the model itself, it is noteworthy to mention that it considers numerous inputs such as several international quotations (e.g. from Platts and Argus), distances between network facilities (refineries, depots and service stations) or demand across the network. Additionally, bearing in mind that the oil companies are legally compelled to introduce/blend biofuels within refined products in order to meet energetic targets, and since different biofuels have different impacts on the energetic target (non-linear relationship), the optimisation model is a non-linear model. The model aims to maximise results (margins) considering product supply and logistics costs. The output of the model is a complex network of downstream supply. It provides the optimal connections between refineries, depots and service stations.

Finally, Galp's downstream planning aims to fulfil customer's demand in over 1,200 Galp's service stations spread around the Iberia (figure 4).

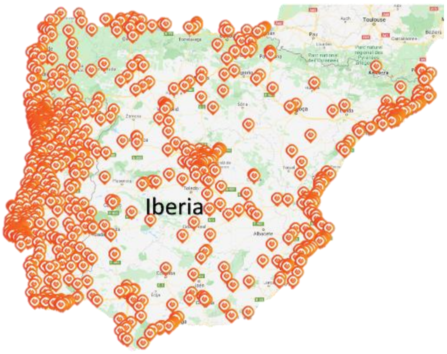

***Figure 4** – Galp's service station in Iberia mainland*

3.2 – Problem's Formulation

Due to legal requirements petroleum companies are compelled to introduce biofuels in their fuel chain. As a result, these companies utilise several reference's prices of fuels and biofuels when negotiating the acquisition or selling of oil products. Notwithstanding each corporation has its own mathematical formula of selling biofuels, the root and similarity is the daily Argus Quotation of FAME or Bioethanol combined with either diesel or gasoline Platts' reference prices.

The problem arises when analysing the evolution of combined pairs of quotations such as FAME (biodiesel) versus diesel and bioethanol (bio-gasoline) with gasoline. Figure 5 outlines the combined daily evolution of FAME and diesel (given as a differential) since 2013 until the beginning of 2020, which reaches a minimum of 60 €/ton and a maximum of 530 €/ton.

Further, the same timeline and framework is suggested in figure 6, although comparing bioethanol and gasoline. In this case, the differential varies from -200 €/ton to 450 €/ton. The non-steady evolution displayed in both figures is the root for this research.

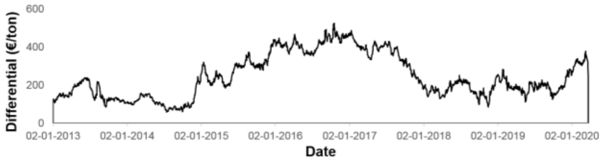

***Figure 5** – Daily differential of FAME and diesel's reference prices since 2013 until 2020.*

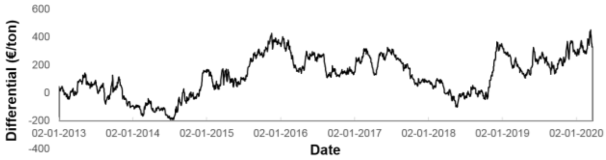

***Figure 6** – Daily differential of bioethanol and gasoline's reference prices since 2013 until 2020.*

The work has the goal to study the Iberian fuel distribution system, taking the perspective of one Iberian player - Galp - and looking into the specific problem of biofuels quotations and its impact in tactical and operational level of Galp's downstream planning. The research aims to analyse the impact of biofuels quotations in the areas of influence of each refinery and depot (i.e. decide which refinery supplies each depot (and what type of fuel) and which depot supply each service station) while meeting all legal requirements such as the energy target - different biofuels have different impacts. Analysing the energy target with different biofuels in different frameworks/scenarios is the challenge proposed by Galp, since knowing with detail the impact that quotations have in the distribution planning is a competitive advantage.

4. Research Methodology

This Research Methodology comprehends four steps: 1 - historical analysis of biofuels and fuels quotations; 2 - build-up of different planning scenario's settings; 3 - programming and testing in Galp's planning software; and 4 - data-driven sensitivity analysis. Figure 7 briefly describes the approach.

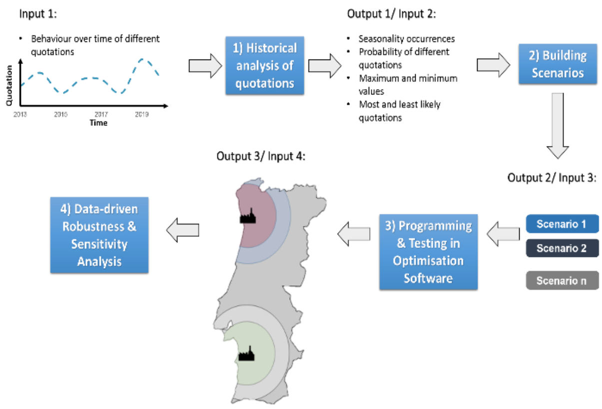

***Figure 7** – Schematic representation of the proposed methodology and its 4 steps.*

5. Methodology Analysis and Results

The goal of this dissertation is to understand the impact of biofuels quotations in the areas of influence of refineries and depots. As a result, FAME and bioethanol quotations are crucial for this study.

A key point for this research was the decision of which Galp's planning model parameters to include in the study. The current downstream optimisation model involves dozens of parameters such as transportation costs, distances between refineries, depots and service stations, several international quotations, energetic targets, contracts between key players, etc. Due to the obvious complexity of studying all the input parameters and their relationship with the biofuels quotations, the author aligned with the Iberian Optimisation Planning and Supply department of Galp decided to study several international reference prices - **the exchange rate between dollar and euro** and **MTBE**, **methanol**, **gasoline** and **diesel** quotations alongside with **FAME** and **ethanol** reference prices.

5.1 – Input 1

As a result, the input of the first stage of the proposed methodology is the behaviour over time of the different international quotations. This analysis is based on reference prices from 2013 to 2019.

The different quotations are described in figures 8, 9 and 10. For the sake of clarity and to avoid sharing sensitive information, these figures do not represent a daily evolution of the different quotations, but a monthly evolution of those (by considering the average per month) and are divided between those 3 figures. Despite this visual simplification, this study was conducted considering the daily evolution of such quotations.

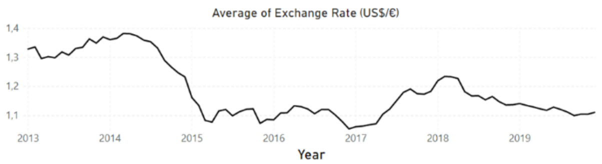

***Figure 8** – Monthly average evolution of the Exchange Rate between US dollar and euro.*

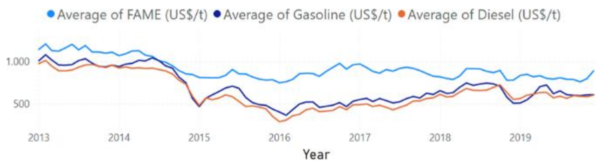

***Figure 9** – Monthly average evolution of FAME (US$/t), Gasoline (US$/t) and Diesel (US$/t).*

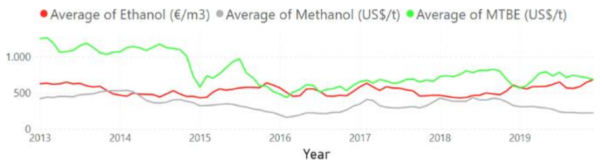

***Figure 10** – Monthly average evolution of Ethanol (€/m3), Methanol (US$/t) and MTBE (US$/t).*

5.2 – 1st Stage: Historical Analysis of quotations

The purpose of this first step is to provide the foundations for the following stage which involves building different scenarios. As a result, and in order to provide key insights of the different quotations, some statistical parameters such as the minimum, maximum and arithmetic mean values, the coefficient of variance, the standard deviation and different percentiles are evaluated.

5.3 – Output 1/ Input 2

Table 1 summarises the different results obtained for each quotation.

***Table 1** - Summarised results of historical analysis of quotations.*

	Exchange Rate (US$/€)	Ethanol (€/m³)	Methanol (US$/t)	MTBE (US$/t)	FAME (US$/t)	Gasoline (US$/t)	Diesel (US$/t)
Mean	1.19	540.15	349.74	807.49	919.71	689.06	638.60
Standard Deviation	0.10	68.61	94.47	220.69	126.81	195.84	194.42
Coefficient of variation (%)	8.40	12.70	27.01	27.33	13.79	28.42	30.44
Minimum	1.04	416.75	160.79	400.25	720.00	336.00	246.75
25th percentile	1.11	475.69	282.83	645.38	822.00	532.69	484.50
50th percentile	1.14	543.13	340.86	739.50	881.00	622.63	590.63
75th percentile	1.28	591.25	418.15	1042.63	979.25	897.50	832.44
Maximum	1.40	714.50	550.90	1390.00	1244.00	1114.00	1042.50

5.4 – Building Scenarios

At this point, the challenge is how to create relationships between the different quotations. Further, these relationships need to translate the fuel market insights and tendencies, and this raises a debating point - the tremendous complexity of such markets. As a result, instead of inferring rules from the market and applying them to the different quotations, the author decided to discover the market rules/tendencies from the historical quotations. Otherwise stated, the idea is to understand tendencies between quotations and discover relationships among them - e.g. in 10 % of the cases, the exchange rate is high, the ethanol is low, the methanol is high, etc. In order to attain such conclusions, specifying whether such quotation is classified as high or low is crucial. The rule for classification *class* of each quotation is defined in equation 1, where *m* stands for the minimum value, *M* represents the maximum value and *mdn* is the 50th percentile (also known as Median value).

$$class = \begin{cases} Low, & \text{if } m \leq x_i < mdn \\ High, & \text{if } mdn \leq x_i \leq M \end{cases} \quad (1)$$

Further, focusing on establishing quotations' relationships, the author built a probability tree diagram. Associated with each tree branch, is a probability of occurrence, which, regarding this study, is always 50 % - due to the definition of the median value, used to separate the *Low* and the *High* branches.

Moreover, since this research requires the study of 7 different quotations, the number of tree branches and, therefore, number of scenarios is 2^7 = 128. Figure 11 illustrates part of the tree diagram.

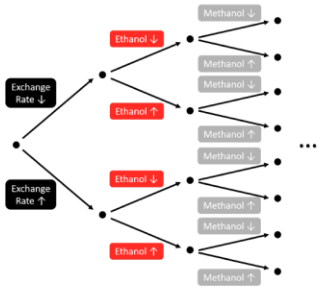

***Figure 11** – Part of the tree diagram.*

The tree diagram framework is useful to overcome the barrier of the abstract thinking of quotations' relationships into 128 possible and measurable scenarios which combine the 7 types of quotations.

Thus, the following step is understanding how many of these scenarios are plausible and decide which ones to study in Galp's planning software, based on their frequency of occurrence. As a result, the author built a cumulative frequency diagram (illustrated by figures 12 and 13).

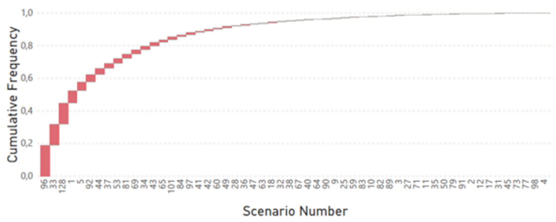

***Figure 12** – Cumulative frequency diagram.*

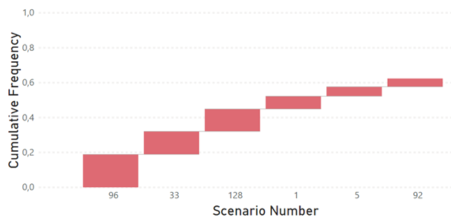

***Figure 13** – A closer look at the Cumulative frequency diagram.*

Further, the author, aligned with Galp's Planning department, decided to study the most frequent 6 scenarios where the number of occurrences exceeds, 90. The 6 most-relevant scenarios are briefly described in table 2.

***Table 2** – Overview of the 7 most frequent scenarios.*

Scenario Number	Frequency (%)	Exchange Rate (US$/€)	Ethanol (€/m³)	Methanol (US$/t)	MTBE (US$/t)	FAME (US$/t)	Gasoline (US$/t)	Diesel (US$/t)
96	18,9	↑	↓	↑	↑	↑	↑	↑
33	13,1	↓	↑	↓	↓	↓	↓	↓
128	12,8	↑	↑	↑	↑	↑	↑	↑
1	7,4	↓	↓	↓	↓	↓	↓	↓
5	5,4	↓	↓	↓	↓	↑	↓	↓
92	4,8	↑	↓	↑	↑	↓	↑	↑

At this point, the author has narrowed down the 128 scenarios to 6. Although, each of them only possesses qualitative attributes, either *High* or *Low*. Since quantitative quotations are required in Galp's downstream planning model, an additional step is required to convert the qualitative information into quantitative inputs. Recapping equation 1, the author decided to use the midpoint of each interval to represent such *Class*.

Finally, it is vivid that different scenarios may have a significant difference from others. Therefore, comparing its results will turn out (in most cases) to be pointless. Hence, the author decided to divide each scenario into 5 scenarios - a baseline scenario + 2 scenarios regarding changes in FAME + 2 scenarios regarding changes in Ethanol. As a result, the 6 scenarios are 6 groups of 5 scenarios where inside each group they can all be compared with their baseline.

5.5 – Output 2/ Input 3

Table 3 illustrates the 30 scenarios to be evaluated and tested in Galp's optimisation software. Each group of scenarios has an associated number (related to the previous studied 6 scenarios (see table 2) and points (a), (b), (c) and (d) which represent either the increase or decrease in a specific biofuel quotation. In each point, only one change is performed compared to the baseline.

Scenario Number	Exchange Rate (US$/€)	Ethanol (€/m³)	Methanol (US$/t)	MTBE (US$/t)	FAME (US$/t)	Gasoline (US$/t)	Diesel (US$/t)
96	1,27	480	446	1065	1063	868	817
(a) ↗ 10% FAME	1,27	480	446	1065	**1169**	868	817
(b) ↘ 10% FAME	1,27	480	446	1065	**957**	868	817
(c) ↗ 10% Ethanol	1,27	**528**	446	1065	1063	868	817
(d) ↘ 10% Ethanol	1,27	**432**	446	1065	1063	868	817
33	1,09	629	251	570	801	479	419
(a) ↗ 10% FAME	1,09	629	251	570	**881**	479	419
(b) ↘ 10% FAME	1,09	629	251	570	**721**	479	419
(c) ↗ 10% Ethanol	1,09	**692**	251	570	801	479	419
(d) ↘ 10% Ethanol	1,09	**566**	251	570	801	479	419
128	1,27	629	446	1065	1063	868	817
(a) ↗ 10% FAME	1,27	629	446	1065	**1169**	868	817
(b) ↘ 10% FAME	1,27	629	446	1065	**957**	868	817
(c) ↗ 10% Ethanol	1,27	**692**	446	1065	1063	868	817
(d) ↘ 10% Ethanol	1,27	**566**	446	1065	1063	868	817
1	1,09	480	251	570	801	479	419
(a) ↗ 10% FAME	1,09	480	251	570	**881**	479	419
(b) ↘ 10% FAME	1,09	480	251	570	**721**	479	419
(c) ↗ 10% Ethanol	1,09	**528**	251	570	801	479	419
(d) ↘ 10% Ethanol	1,09	**432**	251	570	801	479	419
5	1,09	480	251	570	1063	479	419
(a) ↗ 10% FAME	1,09	480	251	570	**1169**	479	419
(b) ↘ 10% FAME	1,09	480	251	570	**957**	479	419
(c) ↗ 10% Ethanol	1,09	**528**	251	570	1063	479	419
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(b) ↘ 10% FAME	1,27	480	446	1065	**721**	868	817
(c) ↗ 10% Ethanol	1,27	**528**	446	1065	1063	868	817
(d) ↘ 10% Ethanol	1,27	**432**	446	1065	1063	868	817

5.6 – Programming and testing in Optimisation Software

The optimisation software used by Galp's planning department is GRTMPS, developed by Haverley. Since GRTMPS was already used in Refining planning, the Downstream Planning Department adapted the model to their needs. As a result, the author did not develop any part of the model but used the software to test the different scenarios. Regarding the model itself, it is noteworthy to mention that it considers numerous inputs such as the 7 mentioned quotation.

As previously stated, the Iberian Peninsula comprehends two different paradigms for Galp either in logistics infrastructures or in Galp's market position. Although, there is another difference, between the Iberian countries. The downstream optimisation model is entirely focused on the Spanish market. Due to several rigid and established contracts in Portugal, the downstream supply of Galp in this country does not suffer relevant changes over time and, when it does, the contracts drive the downstream network composition. Therefore, the dissertation's results and its analysis is entirely focused in Spain supply. Finally, the model itself might be tested within different time horizons (e.g. annual, monthly, semester, quarterly, etc.) for demand. In order to prevent sharing sensitive data, the author choose one specific time horizon for all the scenarios although it is not explicitly described which one.

5.7 – Data-driven Sensitivity Analysis

The key idea of this section is to retrieve relevant information about the downstream diesel and gasoline supply network of Galp under different circumstances. Due to the obvious sensitive information of Galp business, the author carefully displays the results to avoid exposing Galp's sensitive data.

5.7.1 – The 1st segment: From Refineries to Depots

The first part of this analysis focuses on the primary segment of the downstream supply - movements of products from Refineries to Depots. Remembering figure 3, the number of Spanish refineries is 8, however, the Puertollano Repsol's refinery is currently closed. Hence, the model only provides optimal networks regarding the 7 available Spanish refineries (Huelva and Algeciras from Cepsa; Castellón from Bp and Coruña, Bilbao, Tarragona and Cartagena from Repsol).

- **Diesel Network**

The given results are analysed considering two different perspectives. As previously stated, the way each group of scenarios is built allow that all scenarios (a) and (b) may be compared with its baseline scenario since there is only one type of variation. However, it is also possible to compare different groups of scenarios.

In fact, scenario 96 can be analysed alongside scenario 128 since all the inputs are the same except Ethanol's quotation which is higher in scenario 128. Further, the exact same situation happens between scenarios 33 and 1, being the Ethanol's quotation input higher in scenario 33. A slightly different situation occurs between scenarios 1 with 5 and 96 with 92 where all the inputs are equal except FAME's quotation. Between scenarios 1 and 5, FAME's quotation is higher in 5, whereas, between 96 and 92 the same quotation is higher in 96. Starting the analysis by taking a closer look at scenario 96, when FAME's quotations drop 10 % (scenario (b)), the resulting network does not include Bilbao refinery. Therefore, the previous Bilbao supplied depots (in the baseline case) are now mainly supplied by another Repsol refinery - Tarragona. Further, considering an increase in FAME's quotation by 10 % (scenario (a)), the rearranged network entails a significant difference in Huelva refinery since it now supplies 2 new depots. In fact, analysing figure 14, where the volume of diesel moving out of refineries is displayed, those conclusions are supported.

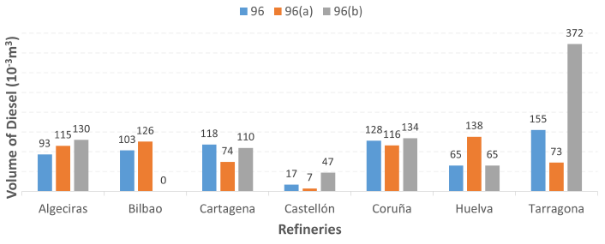

Figure 14 *– Volume of Diesel moving out of Refineries regarding scenario 96 baseline, 96 (a) and 96 (b).*

Since scenario 96 might be compared with scenario 128, it is worth noting that even though the Ethanol's quotation has increased 31 %, the diesel network remains practically the same either in configuration or in terms of volumes (figure 15). This raises an interesting point of debate - does the ethanol's quotation impact the network?

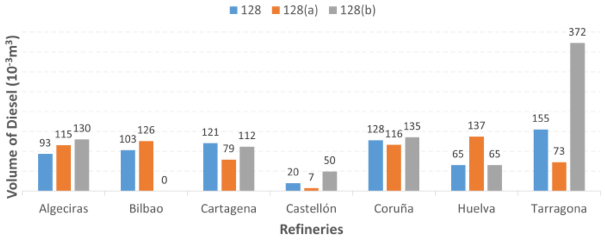

Figure 15 *– Volume of Diesel moving out of Refineries regarding scenario 128 baseline, 128 (a) and 128 (b).*

Further, the same conclusion is withdrawn by comparing scenarios 33 and 1. In other words, even a totally different input (scenarios 33 and 1 do not have a single equal input compared with scenarios 96 and 128) provided the same results - the diesel network remains practically untouched either in configuration or in terms of volume.

Taking a closer look at the diesel network of scenarios 33 and 1 it is noteworthy that when FAME's quotation drops 10 %, Bilbao refinery tends to lose its importance. In fact, bearing in mind that FAME's quotation increases from scenario (b) to the baseline and then to scenario (a), the same happens to Bilbao's refinery importance. On the contrary, with the increase of FAME's quotation, Tarragona's refinery loses importance.

Moreover, scenario 5 is a very interesting one. Analysing its diesel network, illustrated by figure 16, it becomes clear the Bilbao's refinery importance. In either the baseline situation or scenarios (a) and (b) it is vivid the orange domination in the map representing the Bilbao's refinery connections.

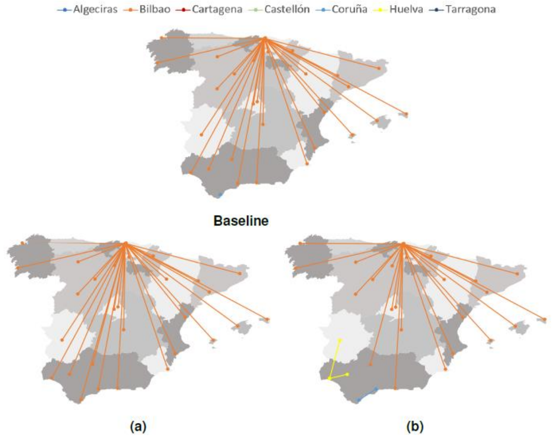

Figure 16 *– Diesel network (1st segment) regarding scenario 5 baseline, 5 (a) and 5 (b).*

Further, a particularly different scenario - 92. Until now, Bilbao's refinery was one of the key points of discussion. Although, in scenario 92, Bilbaos' refinery is not used.

Finally, the comparable pairs of scenarios where the input difference was regarding the Ethanol's quotation were already analysed. However, the comparable pairs where the difference stands on the FAME's quotation input are yet to evaluate. Hence, let's observe scenario 1 with 5 and scenario 96 with 92. Firstly, in opposition to what happened between scenarios with Ethanol's variation, these scenarios have significant changes in its network. This outcome was obvious since all the previous analysis inside each scenario (comparing the baseline with scenarios (a) and (b)) was based on FAME's quotation changes. The only difference between scenarios is the magnitude of that change. Previously, the magnitude was ± 10 % compared to the baseline, although, the magnitude of change between these pair of scenarios is 33 % (scenario 5/96 baseline has a 33 % higher FAME input than scenario 1/92 baseline, respectively). Figures 17 and 18 provide a broader understanding.

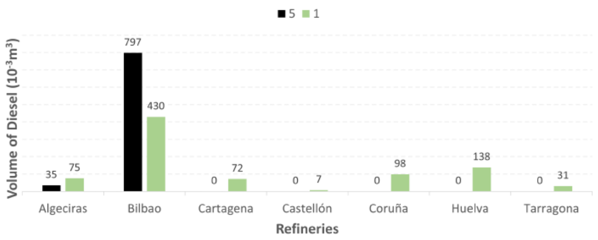

***Figure 17** – Volume of Diesel moving out of Refineries regarding scenario 5 baseline and 1 baseline.*

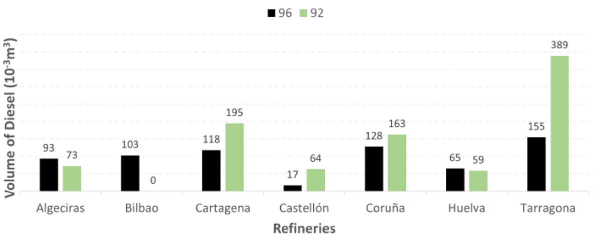

***Figure 18** – Volume of Diesel moving out of Refineries regarding scenario 96 baseline and 92 baseline.*

- **Gasoline Network**

The given gasoline network results are analysed considering the same two different perspectives as the diesel network was - analysis inside a group of scenarios and analysis of comparable pairs of scenarios.

In fact, excluding scenarios 96 and 92, all the scenarios remain almost unchanged with changes in the Ethanol's quotation. Figure 19 (regarding the volume of gasoline moving out of refineries for the group of scenarios 33) illustrates one example of such situation.

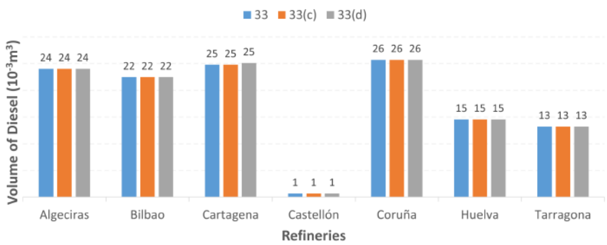

***Figure 19** – Volume of Gasoline moving out of Refineries regarding scenario 33 baseline 33 (c) and 33 (d).*

Further, even considering scenarios 96 and 92, where the network suffer some changes compared to the baseline, the volume of gasoline coming out of each refinery did not suffer meaningful changes. Regarding scenario 96, comparing the baseline with scenario (c), the relevant difference stands in Algeciras' refinery where the volume of gasoline decreases 24 % and in Cartagena's refinery where the volume of gasoline increases 29 %. Further, comparing the baseline with scenario (d), the relevant difference is in Castellón's refinery (the least relevant in terms of volume) where the volume drops 100 %. On the other hand, regarding scenario 92 itself, there are a few changes, comparing the baseline with scenario (c), in Algeciras and Cartagena's refineries. In Algeciras, there is a drop of 33 % of gasoline volume whereas there is an increase of 32\% in Cartagena. Finally, regarding scenario 92 (d) compared with 92 baseline, there is an increase of 70 % in Algeciras and a decrease of 39 % in Coruña. There are also lighter changes in Huelva and Tarragona.

The second part of this analysis is an inter-scenario analysis (between comparable pairs of scenarios). Reinforcing the idea of the light changes derived by the Ethanol's quotation is the analysis between scenarios 96 with 128 and 33 with 1. It is vivid that not only the network distribution but also the amount of gasoline suffers minor changes. On the contrary, changes in FAME's quotation real impact the gasoline network as well. Figures 20 and 21 provide a broader understanding.

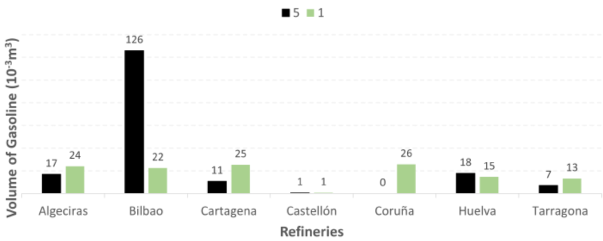

***Figure 20** – Volume of Gasoline moving out of Refineries regarding scenario 5 baseline and 1 baseline.*

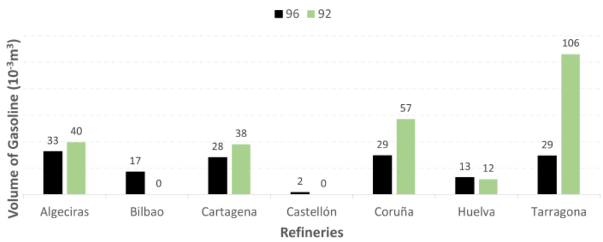

***Figure 21** – Volume of Gasoline moving out of Refineries regarding scenario 96 baseline and 92 baseline.*

Notwithstanding this is a gasoline network, the changes of FAME's quotation between different scenarios have quite an impact. It is also interesting that the same key conclusions can be withdrawn. On one hand, in both cases (figures 20 and 21) the importance of Bilbao's refinery arises when FAME's quotation increases. On the other hand, the importance of Tarragona's refinery decreases as FAME's quotation increases.

5.7.2 – A deeper depot analysis

The second part of this analysis focuses on the connection point between the primary and the secondary segment of the downstream supply - Depots. Remembering figure 3, there are various depots spread around Spain that Galp (and, obviously, Galp's competitors) may utilise to fulfil costumer's demand.

This analysis will be only focused on the diesel network since variations of Ethanol did not significantly impact the gasoline network as outlined in the previous section (remembering that the idea of studying the gasoline network was to analyse changes in Ethanol's quotation). Further, section 5.7.2 describes the similarities between scenarios for the secondary segment of the downstream network where becomes clear that a deeper depot analysis would be pointless.

Regarding the obtained results, it is interesting that in every scenario, regardless of if it is baseline, (a) or (b), the most relevant depot in the network is located in the east of Spain, near Valencia. Put differently, it is nearby Valencia that is stored more diesel in one single depot. Additionally, another important depot is always located in the northwest of Spain, in Corunã. Hence, regardless the different inputs, the strategic positions of supply are well defined and very distant from one another. Figure 22 illustrates the bubble map of scenario 33 representing the volumes of diesel in depots where it is visible the underlying conclusion.

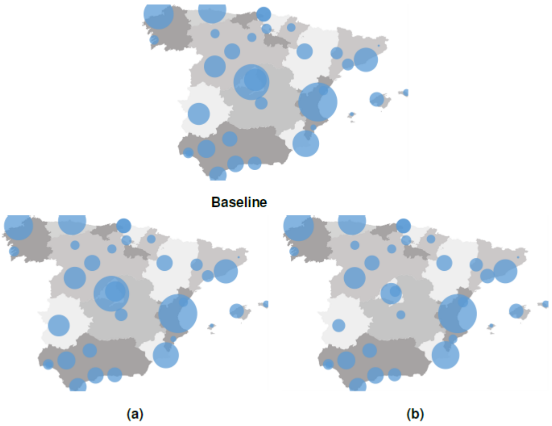

Figure 22 – Bubble maps representing the volume of diesel, in depots, for scenarios 33 baseline, 33 (a) and 33(b).

Further, taking a closer look at scenarios 96 and 128 altogether (remembering that the only difference between them is the Ethanol's quotation input), it is important to note that the variation between (a) and (b) compared to each baseline is the same. In order to get a broader picture of this situation, figure 23 illustrates a comparison between those scenarios in terms of diesel variation inside depots (in volume) between baselines where becomes clear the really low impact of Ethanol in the network (the highest variation, in module, is around 10 %).

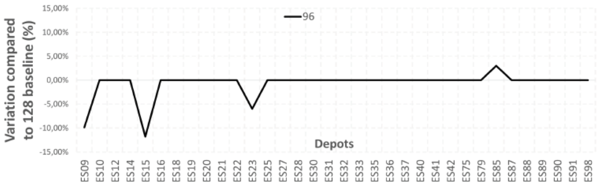

Figure 23 –Diesel variation inside depots (in volume) of scenario 96 baseline compared to scenario 128 baseline.

In fact, the same conclusion can be withdrawn from the analysis of scenarios 33 and 1, which, in the same way, only diverge in the Ethanol's quotation. Once again, the variation between each baseline with (a) and (b) is the same in both situations. Figure 24 provides a broader comparison between both scenarios where it is vivid, again, the low impact of Ethanol's quotation in the network (the highest variation, in module, is around 1,5 %).

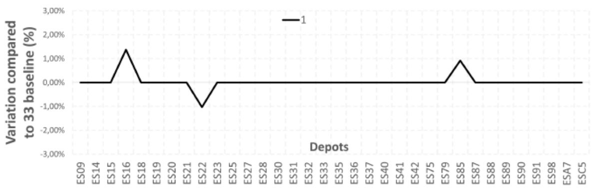

Figure 24 –Diesel variation inside depots (in volume) of scenario 1 baseline compared to scenario 33 baseline.

On the contrary, Fame's quotation has a higher impact in the network. Put differently, in all groups of scenarios (except in scenario 92) there is a variation of at least 70 % compared to each baseline. Not only there is a rearrange in the network. but also, in some cases, there is a need to introduce/exclude different depots compared to the baseline. This situation happens for scenarios 96 and 128.

Finally, aligned with the last idea, the author decided to study the impact of FAME's variation within different comparable scenarios. Hence, figures 25, 26 and 27 illustrate such comparison between scenarios 96 with 92 and 5 with 1 where it is portrayed the high impact in the network - between scenarios 96 and 92 the variation reaches 150 % and there are new depots in scenario 92; and between scenarios 5 and 1 the variation reaches 40 %.

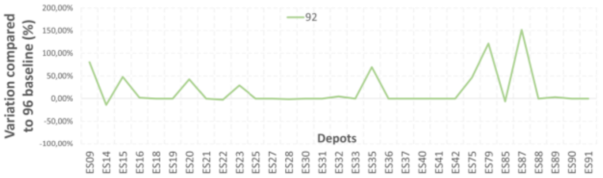

Figure 25 –Diesel variation inside depots (in volume) of scenario 92 baseline compared to scenario 96 baseline.

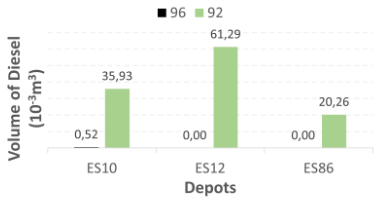

Figure 26 –Volume of diesel inside depots regarding scenario 96 and 92.

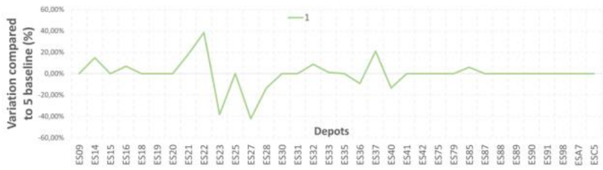

Figure 27 –Diesel variation inside depots (in volume) of scenario 1 baseline compared to scenario 5 baseline.

5.7.3 – The 2nd segment: From Depots to Service Stations

The last part of this analysis focuses on the secondary segment of the downstream supply - movements of products from Depots to Service Stations. From figure 3 becomes clear that the number of supply locations escalates comparing to the primary segment. This analysis will focus on both diesel and gasoline networks.

- **Diesel Network**

The idea beyond this analysis is to capture a broader view of the different outcomes caused by changes in FAME's quotation.

Align with the previous analysis, both intra-scenario and inter-scenario analysis is conducted. This time, the idea is to visually compare each network map since Service Stations' demand do not change and the different depots are already analysed (see section 5.7.2). Hence, due to the huge number of maps, the resulting maps for scenario 96 are illustrated, in figure 28. as an example of this approach.

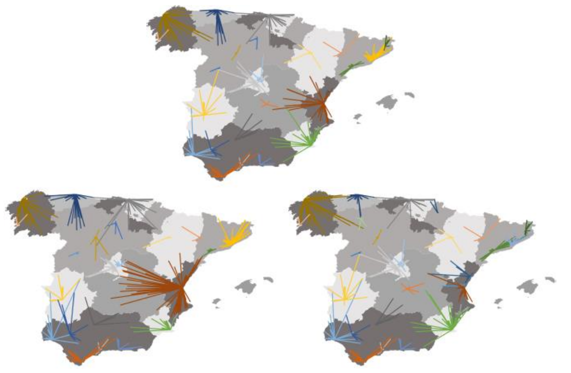

***Figure 28** – Diesel network (2nd segment) regarding scenario 96 baseline, 96 (a) and 96 (b).*

These results follow the exact same tendencies of the ones previously described in sections 5.7.1 and 5.7.2 - changes in FAME's quotation cause a higher impact in the diesel network than changes in Ethanol's. Further, even comparing scenarios 96 with 92 and 1 with 5 - remembering that the only difference is FAME's quotation input - the same conclusion is attained. Finally, on the other hand, comparing scenarios 96 with 128 and 33 with 1, the idea of Ethanol's quotation not impacting the diesel network is confirmed.

- **Gasoline Network**

Regarding the secondary segment of the gasoline downstream network, it is crucial to focus on the connections between depots and service stations. Further, within this section, the previous decision of not to deeper explore the depots regarding the gasoline network is justified.

To provide a broader understanding, between scenario 96 and 128 only 6 out of 492 service stations (around 1 %) received gasoline from a different depot. Further, even a smaller amount of differences is found between scenarios 33 and 1 where only 4 service stations (less than 1 %) were served by different depots. Herein lies the crux of the matter. Remembering that the gasoline network is primarily explored to understand the impact of variations in Ethanol's quotation, it would be irrelevant to address a specific section to address such meaningless impact.

On the other hand, comparing the gasoline network between comparable scenarios where FAME's quotation input is different provides different results. In fact, between scenarios 96 and 92 around 40 % of the service stations were supplied differently. Additionally, around 14 % of the service stations were supplied differently if considered scenarios 1 and 5.

Therefore, due to the similarities of the network with only changes in Ethanol's quotation, this section only provides visual description of the network for scenarios 96 and 92. Figures 29 and 30 illustrate the secondary segment of the gasoline network for those groups of scenarios, respectively. This way, it is ensured that the similarities are visible through comparing each baseline with scenarios (c) and (d) and the differences between the comparable groups of scenarios.

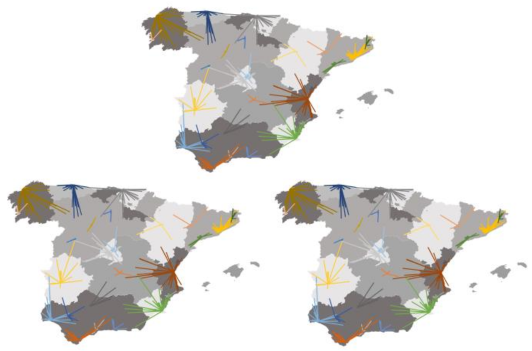

***Figure 29** – Gasoline network (2nd segment) regarding scenario 96 baseline, 96 (c) and 96 (d).*

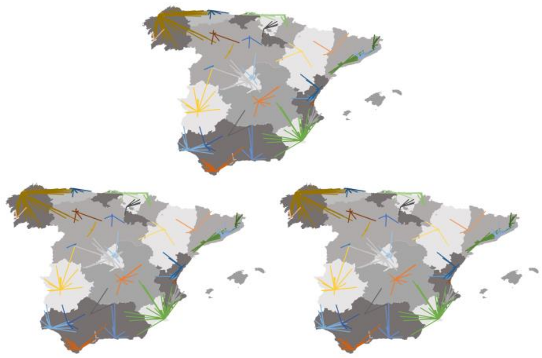

***Figure 30** – Gasoline network (2nd segment) regarding scenario 92 baseline, 92 (c) and 92 (d).*

5.7.3 – Scenario's impact on Downstream Supply Costs

Finally, table 3 portrays the different impacts of each scenario in the Objective Function (total cost of the Downstream Supply) and the Diesel and Gasoline Purchase costs. In order to avoid sharing sensitive data, the value itself of each cost is dully presented without any associate monetary unit. Although, for the sake of consistency, all the results share the same magnitude and monetary unit.

By taking a closer look at table 3, it is possible to withdraw some conclusions. Firstly, as expected, in every group of scenarios, scenarios (a) and (c) cause an increase in the total cost (objective function). Put differently, scenarios which portray a quotation increase drive the objective function to an increase. Additionally, it is interesting that in all scenarios (except scenario 5), the variation (in module) regarding the objective function value is bigger for scenarios (a) and (b). This confirms that a variation in FAME's quotation has, typically, a higher impact in the network resulting in additional costs. Secondly, two more conclusions can be attained. On one hand, it is clear that a variation in ethanol's quotation does not impact the diesel purchase cost, however it does impact the gasoline purchase cost. On the other hand, a variation in FAME's quotation impacts both types of costs. In fact, apart from scenario 5, the impact is more relevant in the diesel purchase cost.

Table 3 – *Overview Downstream Supply Costs per scenario.*

Scenario	Objective Function		Diesel Purchase		Gasoline Purchase	
	Value	Variation (%)	Value	Variation (%)	Value	Variation (%)
96	248,24	–	160,51	–	32,85	–
(a) ↗ 10 FAME	249,08	0,34	161,14	0,39	32,85	0,01
(b) ↘ 10 FAME	247,51	-0,29	159,44	-0,67	32,91	0,18
(c) ↗ 10 Ethanol	248,36	0,05	160,51	0,00	32,96	0,35
(d) ↘ 10 Ethanol	248,13	-0,05	160,51	0,00	32,74	-0,35
33	151,42	–	84,78	–	18,88	–
(a) ↗ 10 FAME	151,61	0,13	84,73	-0,06	18,82	-0,30
(b) ↘ 10 FAME	150,98	-0,29	84,98	0,23	18,89	0,07
(c) ↗ 10 Ethanol	151,53	0,07	84,78	0,00	18,98	0,57
(d) ↘ 10 Ethanol	151,31	-0,07	84,78	0,00	18,77	-0,56
128	248,60	–	160,55	–	33,17	–
(a) ↗ 10 FAME	249,44	0,34	161,18	0,40	33,18	0,04
(b) ↘ 10 FAME	247,86	-0,30	159,47	-0,67	33,25	0,22
(c) ↗ 10 Ethanol	248,74	0,06	160,61	0,04	33,25	0,24
(d) ↘ 10 Ethanol	248,45	-0,06	160,51	-0,02	33,06	-0,34
1	151,16	–	84,72	–	18,68	–
(a) ↗ 10 FAME	151,35	0,13	84,65	-0,08	18,66	-0,14
(b) ↘ 10 FAME	150,72	-0,30	84,92	0,24	18,69	0,01
(c) ↗ 10 Ethanol	151,25	0,06	84,78	0,07	18,71	0,12
(d) ↘ 10 Ethanol	151,07	-0,06	84,72	0,00	18,59	-0,53
5	151,53	–	84,70	–	18,40	–
(a) ↗ 10 FAME	151,55	0,01	84,71	0,02	18,27	-0,72
(b) ↘ 10 FAME	151,46	-0,05	84,78	0,10	18,48	0,42
(c) ↗ 10 Ethanol	151,62	0,06	84,78	0,09	18,39	-0,06
(d) ↘ 10 Ethanol	151,43	-0,06	84,69	0,00	18,30	-0,55
92	245,49	–	157,49	–	32,71	–
(a) ↗ 10 FAME	246,89	0,57	158,76	0,81	32,85	0,42
(b) ↘ 10 FAME	244,56	-0,38	156,68	-0,52	32,59	-0,37
(c) ↗ 10 Ethanol	245,60	0,05	157,49	0,00	32,83	0,35
(d) ↘ 10 Ethanol	245,38	-0,05	157,49	0,00	32,59	-0,37

6. Conclusions and Future work

Experts advise that current oil and gas reserves would last merely a few more decades. To outstrip the accelerating energy demand and the reducing of petroleum reserves, fuels such as biodiesel and bioethanol are in the cut-edge of the alternative technologies. It is well-established that vehicle transportation essentially depends on petroleum-based fuels such as gasoline and diesel. Thus, an alternative fuel must be technically feasible, economically competitive, environmentally adequate, and easily available. Accordingly, biodiesel and bioethanol blended with either diesel or gasoline play an important role in downsizing pollutant emission levels while meeting national and European legislation.

The downstream planning of fuel distribution is a complex problem, since the number of demand locations escalates when including the primary and secondary segments. The complexity also derives from the fact that unique products are present, with different supply locations and constraints. The goal of this Master Thesis dissertation is to study the Iberian fuel distribution system, taking the perspective of one Iberian player - Galp - and looking into the specific problem of biofuels quotations and its impact in tactical and operational level of Galp's planning while meeting all legal requirements.

Following the proposed research methodology, the relevant results are portrayed. The key results indicate that FAME's quotation has a larger impact in the downstream network compared to the Ethanol quotation's impact. This impact can be understood from different perspectives. Either an impact in the network design or an impact in the downstream supply costs.

Regarding FAME's quotation and its impact on the diesel network, it is noteworthy that the importance of Bilbao's refinery arises when FAME's quotation increases. On the contrary, the importance of Tarragona's refinery decreases as FAME's quotation increases. This raises an interesting point of discussion. Perhaps, a future research might be developed in order to create a framework to predict FAME's quotation. With that basis, Galp could renegotiate some contracts and take a competitive advantage in those refineries.

The impact of FAME's quotation in the network design goes beyond the diesel network and causes changes in the gasoline network as well. On the contrary, Ethanol's quotation does not drive major network rearranges. Finally, the biofuels quotations' impact on the downstream supply cost is also different. On one hand, a variation on FAME's quotation causes a higher impact on the total supply network cost compared to a change in Ethanol's quotation. On the other hand, it is also clear that a variation in ethanol's quotation does not impact the diesel purchase cost whereas a variation in FAME's quotation impacts both diesel and gasoline purchase costs.

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