# The Estimation of Economic Costs of Operation of the Delimara Extension Power Station Equipment Using Different Types of Fuel

Report Submitted by Enemalta Corporation in the Context of the Application for IPPC Operating Permit for the Delimara Power Station Extension

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**Executive Summary**

For the purposes of the IPPC permit for the operation of the Delimara Power Station Extension (DPSE), Enemalta is presenting a study to estimate the economic costs of operating DPSE under different three types of fuel, namely Heavy Fuel Oil (HFO), Gasoil and Gas.

The study covers the financial costs, which are costs which are disbursed directly by Enemalta, and which would in consequence have implications for the financial sustainability of the Corporation and on the direct costs of electrical energy to the Maltese economy. The study also considers estimates of the externality cost of emissions under the three fuels, so as to derive the aggregate economic costs which impinge on the economy and on society at large. In line with the Terms of Reference and with the use of the standard incremental approach, the effects of the use of the different types of fuel are considered on the basis of plant already purchased for the DPSE and the existing plant.

In a baseline model founded on reasonable, but potentially varying, expectations about the future, the use of HFO to fuel the DPSE is found to be significantly more advantageous from a financial viewpoint. This is summarized in the prime dynamic cost per MWh of electricity produced as shown in the Table below.

| Prime Dynamic Cost | Cost/MWh |
|---|---|
| HFO | 87.40 € |
| Gasoil | 131.56 € |
| Gas | 94.30 € |

HFO also emerges to be marginally more advantageous from an economic viewpoint, that is taking also into account the cost of emissions. Risk considerations do not point to any type of fuel being preferred over another.

The study focuses also on the robustness of the results to changes in market and other conditions. The financial advantage of HFO is robust to sensitivity assessments and actually improves in conditions of energy efficiency in consumption, the utilisation of alternative energy sources and an increased reliance on inter-connection facilities. The economic advantage of HFO relative to Gas may be eroded chiefly by higher electricity demand and by an increase in the shadow prices of emissions, amongst other factors.

In the circumstances, a policy of flexibility in terms of the ability to use different types of fuel is advisable especially within the context of the dynamics which will be conditioning the energy market over the coming years. There is no single unequivocal answer as to the cheapest cost solution regarding the type of fuel which the country should be utilising over the forthcoming 20-year period. It will be essential for the country to be in a position to choose between different types of energy sources from time to time, and not necessarily to commit to any single source for a protracted period. At the same time, it will be crucial for such technology to be operated in the most efficient manner possible, to optimise financial and economic performance and minimise any attendant risks.

**The Estimation of Economic Costs of Operation of the Delimara Extension Power Station Equipment Using Different Types of Fuel**

1. <u>Objectives</u>

For the purposes of obtaining the IPPC permit for the operation of the Delimara Power Station Extension (DPSE), the Malta Environment and Planning Authority (MEPA) has requested Enemalta to conduct a study to provide estimates of the economic costs of operating DPSE under different three types of fuel, namely Heavy Fuel Oil (HFO), Gasoil and Gas. This report presents the findings of this study.

It is to be noted at the outset that due to the infrastructural adjustments required, the option of fuelling the Delimara Power Station with Gas cannot in practice be implemented prior to 2015. Therefore, the request for the IPPC permit at this stage would only cover the use of HFO and Gasoil. Nevertheless, in compliance with the request by MEPA, and also in consideration of the fact that the study covers the period running to 2020, the implications of the Gas option are covered by this study.

The purview of the study covers the **economic costs** of operation of the DPSE under the three types of fuel, to include:

- **financial costs**, which are costs which are disbursed directly by Enemalta, and which would in consequence have implications for the financial sustainability of the Corporation, and, under the current system of cost recovery in electricity tariff setting operated by the Malta Resources Authority, on the costs of electrical energy to the Maltese economy;
- **externality costs**, which are costs which impinge on the economy and on society at large but for which no financial outlay is effected by Enemalta – chief among these costs which are relevant for the purposes of this study would be those related to emissions to the environment, which would depend upon the choice of fuel within the context of a given technology.

A further consideration which would be relevant in this regard would be the **costs associated with operational risks** that may arise as a result of the use of the different types of fuel. From a methodological perspective, while financial and economic costs are subject to quantitative assessments, the costs of operational risks, which arise out of extreme events with low probability of occurrence, are not as readily amenable to a quantitative assessment as would be typically undertaken through an expected value analysis to characterise the implications of uncertainty. Therefore, the costs of operational risk are in this study subject to a qualitative analysis, involving mainly consideration of preventive and remedial measures aimed at cost minimisation, and in ascertaining whether the use of any kind of fuel poses special risks compared to another.

An important principle adopted in this analysis is the **incremental** concept. This is a standard approach applicable in cost-benefit assessments, and implies that only the incremental effects of a decision are considered to be relevant in the evaluation of a decision. In this case, the incremental effects of the use of the different types of fuel are thus considered on the basis of **plant already purchased for the DPSE and the existing plant**. Only additions and modifications needed to accommodate the use of different types of fuels, but not alternatives, to the plant already purchased for the DPSE and the existing plant are considered in this study. In other words, the existing plant and the plant acquired for the DPSE are considered to be "sunk" decisions, which are not influenced by the fuel choice. On the other hand, the equipment already available and committed to is a determining factor in the choice of the type of fuel.

## 2. Methodology

The methodology adopted in this study is based on the consideration of incremental costs under three scenarios designed to capture the research questions of the study, as follows.

**Scenario I:** Fuelling the DPSE through the use of HFO or Gasoil, depending on which of the alternatives is cheaper from a financial perspective. *A priori*, it can be stated that HFO would typically involve lower financial costs from the perspective of fuel price, but it would also typically result in higher emissions, and hence, potentially higher externality costs. This scenario would involve no relevant changes, from an incremental viewpoint, to the running of the existing power station in Delimara, nor to the infrastructure of the technology committed to for the purposes of the extension.

**Scenario II:** Fuelling the DPSE through the exclusive use of Gasoil. This would *a priori* involve a higher cost of fuel purchase compared to Scenario I, but potentially lower costs of emissions. As in Scenario I, there would in this scenario be no relevant changes, from an incremental viewpoint, to the running of the existing power station in Delimara, or to the infrastructure of the technology committed to for the purposes of the extension.

**Scenario III:** Fuelling the DPSE through the exclusive use of Gas, which will require specific arrangements for the importation of this fuel through a pipeline infrastructure involving an additional capital expenditure of circa USD320 million[1,2]. Annex 1 provides details on the options considered in this regard. An important aspect of this scenario is the fact that the development of Gas importation infrastructure would necessarily be capable of serving both the existing as well as the extension elements of the Delimara Power Station. This is relevant to the application of the incremental methodology, in that, in addition to the consideration of the investment cost to develop the pipeline associated with this scenario, consideration would also need to be taken of:

- the changes in operational costs of the existing plant as a result of changing the fuel used to gas from, gasoil, which is fuel currently being used. details are given in the development of the financial and economic cost models below;
- the additional capital expenditure involved in converting the existing plant to a capability of running on Gas, estimated at around €35 million;
- an element of additional investment expenditure which would be needed to render the equipment committed to on extension element capable of running on Gas, estimated at €27.5

[1] Monetary values in this study are reported in euro, unless the original source of data specifies values in another currency, typically US dollars.
[2] The source of this information is an internal study conducted by Enemalta. Values are expressed in USD, which was the currency utilized for the derivation of cost estimates for the study.

million – combined with the USD320 million expenditure on the pipeline infrastructure itself, this brings the cost of investment to €273 million[3].

In the context of this analysis, a scenario where the development of the Gas infrastructure is not utilised to fuel also the existing equipment on Gas is not considered, because the net incremental costs of converting the existing equipment to run on Gas, at €35 million, will be more than covered, from the financial and economic viewpoints, from the savings on running costs and on emissions. It is furthermore to be noted that a scenario whereby the infrastructural cost of developing the pipeline is apportioned to extension element of the Delimara Power Station, while ignoring the implications for the existing element, is not considered to be adequate, due to the fact that the pipeline infrastructure is not malleable.

The methodology adopted in this paper develops financial (Section 3) and economic (Section 4) cost models for each of the three scenarios based on the incremental approach, in order to determine their relative desirability. This is followed by a sensitivity analysis of the results obtained in Section 5, in order to test the robustness of the conclusions to shocks which may affect the model in the future. This is followed by a qualitative discussion on risks involved under each scenario in Section 6. The study concludes by deriving a number of key implications and recommendations.

## 3. The Estimation of Financial Costs

The relevant costs considered for this study under each scenario from the financial perspective of Enemalta include:

- the operational costs, which in Scenario III would consider the incremental element of fuelling the existing plant on Gas rather than Gasoil;
- investment costs, which are only relevant in Scenario III in the context of developing the pipeline infrastructure and converting equipment to be suitable for Gas operation – such investment cost would be netted from the residual value at the end of the time horizon used for the analysis.

The time horizon used for the analysis spans a 20-year period from 2012 to 2031. This choice was done so as to cover the entire period when the DPSE can be expected to be in commission. In order to bring costs to present value, a discount rate of 5% is used. This is the rate recommended for infrastructural projects under the EU Guidelines relating to Cohesion and ERDF funding. All data shown is at constant 2010 prices, such that the impact of inflation is excluded from the study.

An essential starting point in the development of the financial cost model is to ascertain the role which the DPSE will play in electricity generation in Malta, which will in turn determine the total operational cost, as well as the spreading of investment cost per unit of electricity generated.

[3] An average exchange rate for the US dollar to euro of 1.3 is assumed in this study.

3.1 The Role of DPSE in Electricity Generation in Malta

The demand for electrical power in Malta, for the time period used for the analysis, is based on an estimated demand of 2,135,000MWh in 2010, with a projected growth rate of 0.5% per annum thereafter. The relatively subdued rate of growth takes into account:

- the increase in the price of energy in recent years which is likely to be protracted in future, and which is leading to more efficient energy use;
- the reliance on alternative sources of energy, also in view of Malta's international commitments in this regard;
- the changing structure of Malta's productive base, which is tending to shift towards less energy intensive service activities.

It is thus assumed that energy to be serviced by Enemalta will amount to 2,157,000MWh in 2012, 2,241,000MWh in 2020 reaching 2,367,000MWh by 2031.

The way in which Enemalta expects to meet this demand is affected by the following considerations:

- the Marsa Power Plant will be decommissioned by end 2013;
- the DPSE, with a 144MW capacity, will commence service in May 2012;
- the interconnector to the European grid, with a 200MW capacity, will be brought on line in October 2013;
- the existing Delimara Power Station plant is assumed to remain in service for the purposes of this analysis.

For reasons of optimising operational efficiency and economic and financial costs, Enemalta will seek to supply energy output to meet demand by utilising facilities in the following order of preference:

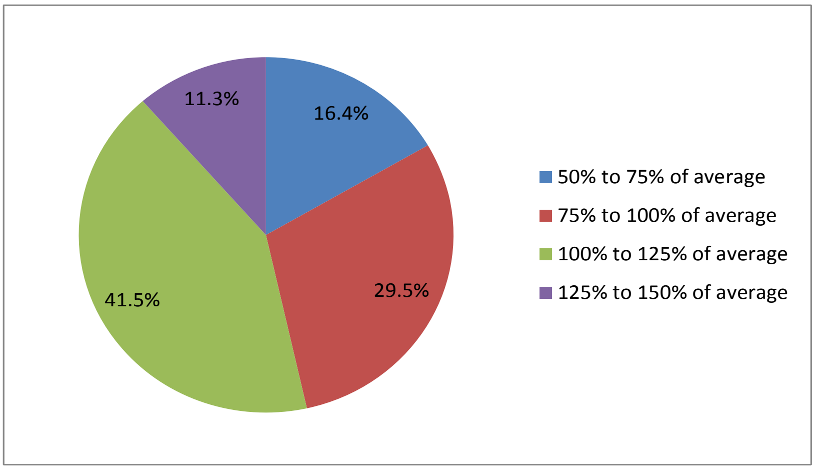
*First preference* - the interconnector to the European grid, which is expected to optimise costs from both the financial and emissions perspective, and is also a flexible source which can rapidly be altered to meet demand fluctuations up to its maximum capacity of 200MW;

*Second preference* - the DPSE plant, which is relatively modern and has better operating efficiency parameters compared to the existing plant;

*Third preference* – the existing Delimara Power Station plant.

The extent to which each of these three facilities will be utilised depends heavily on the hourly variations in electricity demand. If, for example, the demand for electricity in 2031, at 2,367,000MWh, were to be perfectly evenly distributed across the 8760 hours in a year, this would imply a demand of 270MW in each and every hour. Of these, 200MW would be constantly supplied through the interconnector, and 70MW by the DPSE plant, requiring no further electricity generation facilities, and actually potentially pointing to the possibility of a smaller DPSE plant. In practice, however, there would be wide variations in demand during the year. On the basis of 2010 data, Chart 1 shows that on an hourly basis, electricity demand can vary substantially from the average. For 16.4% of the time, for instance, demand in 2010 was between 50% and 75% of the average, while for 11.3% of the time, demand exceeded the average by at least 25%. Continuing on the example of the 270MW average hourly demand, should demand in a particular hour exceed the average by, say 40%, then demand would reach 378MW, requiring the input of the 200MW from the interconnector, the 144MW from DPSE, and the utilisation of other facilities as well. Clearly, in times when demand is 40% below the average, in this case at 162MW, the input from the interconnector would suffice. Therefore, the extent of demand variability will determine the amount of utilisation of the DPSE. Further complicating this decision is the fact that local power generating infrastructure is divided into units which, once switched on, must be kept operating for a minimum number of hours to ensure their efficient operation.

**Chart 1: Distribution of Hourly Demand for Electricity**




*Source: Enemalta*

The demand forecast, applied with the hourly variability patterns in 2010, and combined with the rules for preference and efficient operation of the facilities available, give a power generation plan as indicated in Chart 2. The Marsa plant will continue to play a role in power generation in 2012, accounting for around one-third of power generated by Enemalta, which role will diminish significantly in 2013 and will be completely absent in 2014. The DPSE will also account for around a third of power generation in 2012, and for an even large proportion, close to a half in 2013. With the full availability of the interconnector facility from 2014 onwards, the DPSE will be generating around one-fourth of the electrical energy sold by Enemalta. Thus, the interconnector facility will be responsible for close to three-fourths of electrical power supplied by the Corporation. The existing Delimara plant, which is expected to produce one-third of electrical power in 2012 and one-fourth in 2013, will be accounting for no more than 2% of all electrical power supplied by Enemalta from 2014 onwards. This information is provided in numerical form for selected years in Table 1.

**Chart 2: Expected Power Generation Plan**

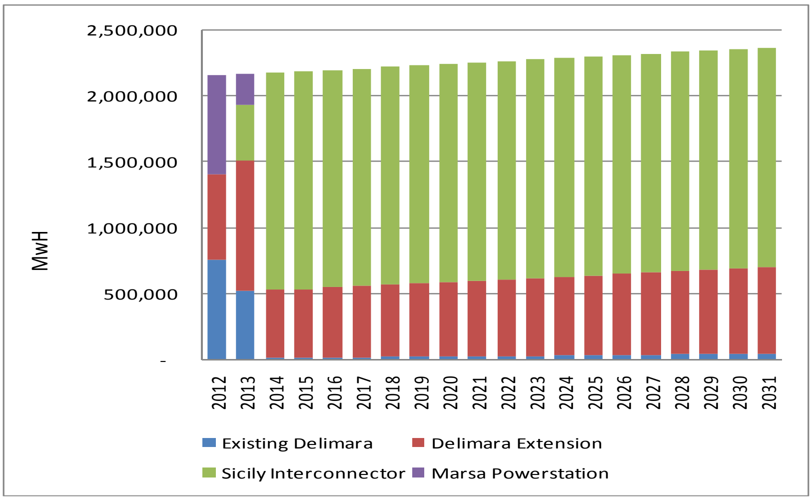



**Table 1: Expected Power Generation Plan in Selected Years**

| MWh | 2012 | 2013 | 2014 | 2031 |
|---|---|---|---|---|
| Marsa Powerstation | 750,706 | 233,876 | - | - |
| Existing Delimara | 756,576 | 520,020 | 16,862 | 48,830 |
| Delimara Extension | 649,728 | 988,721 | 512,605 | 652,827 |
| Sicily Interconnector | - | 425,177 | 1,645,056 | 1,665,282 |
| **Total** | 2,157,010 | 2,167,794 | 2,174,523 | 2,366,939 |

Underpinning these results is the calculation on the number of hours in each year for which the different power generation facilities will be utilised. Table 2 shows this information for selected years. From 2014 onwards, the inter-connector facility at 8,757 hours, would be in use practically all year round. Malta will be dependent on DPSE to fulfil its energy needs for between 6,900 and 7,437 hours between 2014 and 2031. The existing Delimara Power Station infrastructure will be in use for between 569 and 1,338 hours during the same period.

**Table 2: Use of Electricity Generation Facilities**

| *Hours in a year* | Inter-connector | DPS Extension | DPS Existing |
|---|---|---|---|
| 2014 | 8757 | 6900 | 569 |
| 2020 | 8757 | 7128 | 809 |
| 2031 | 8757 | 7437 | 1338 |

3.2 <u>The Modelling of Operational Costs</u>

In modelling operational costs under the three scenarios, costs are broadly divided into:

- the cost of fuel purchases, which is a major element in this regard;

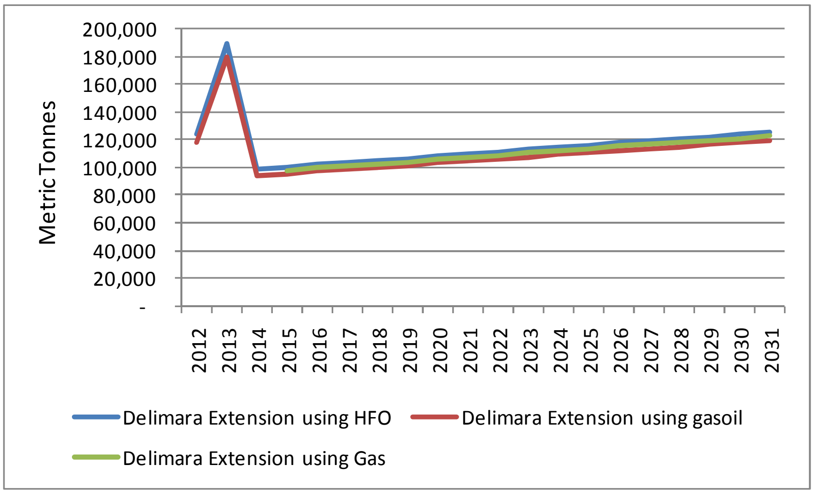
- all other operational costs, a substantial part of which would actually depend on the volume of fuel used, or its cost.

In turn, the cost of fuel purchased is modelled as the product of the volume of fuel used and its expected price. With the operational load on DPSE as obtained through the model described in Section 3.1 above, the expected use of fuel for each year in the analysis period under each of the three scenarios is depicted in Chart 3. The information in Chart 3 was obtained using technological conversion parameters transforming energy output in MWh into metric tonnes of fuel needed to produce such output. These were determined through the use of a model which indicates, for each type of fuel, the amount of fuel consumption per hour depending on variables such as:

- the number of machines operating within the plant;
- the number of hours for which such machines would have already been in operation;
- general declines in the efficiency of machinery over time, and the restoration of such efficiency through periodic maintenance.

In general terms, there are no significant variations in fuel use per MWh of electricity produced. On average, 0.192MT of HFO is needed per MWh of electricity produced, while the comparable figures for Gasoil and Gas are 0.183MT and 0.188MT respectively. There are not significant fluctuations in these figures over time either, with the range for these fuel consumption parameters being contained to within -0.6% to +0.2% of the 20-year time series average. It is furthermore to be noted that consumption figures for Gas start in 2015, the first year when such activity can be reasonably expected to start operating given the infrastructural investment required in this case.

**Chart 3: Projected Use of Fuel in DPSE Under Each Scenario**

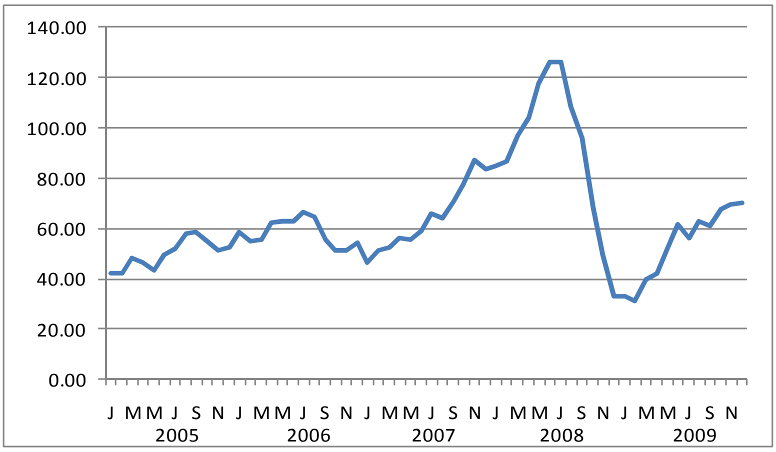



Prices of fuel are subject to obvious considerable uncertainty with respect to their forecasts. Chart 4 shows the volatility in average monthly prices of crude oil over a five-year period from 2005 to 2009. The chart indicates the detachment of such prices from any predictable developments in economic fundamentals and towards the forces of financial market speculation. The average price for the period shown in the Chart stood at USD63.55/barrel of crude oil, with a maximum of over USD126/barrel and a minimum of USD36/barrel. The standard deviation stood at almost 34% of the mean.

It is therefore understandable that any forecast provided in this regard can at best be tentative. However, this variable is crucial to the determination of the costs which are the subject of this model. It is partly for this reason that the analysis presented in this paper is strongly rooted not only in providing a baseline forecast, but also in assessing the extent to which deviations from such forecasts may influence the decision-making process. In this respect, the sensitivity analysis presented in Section 5 of this study is crucial.

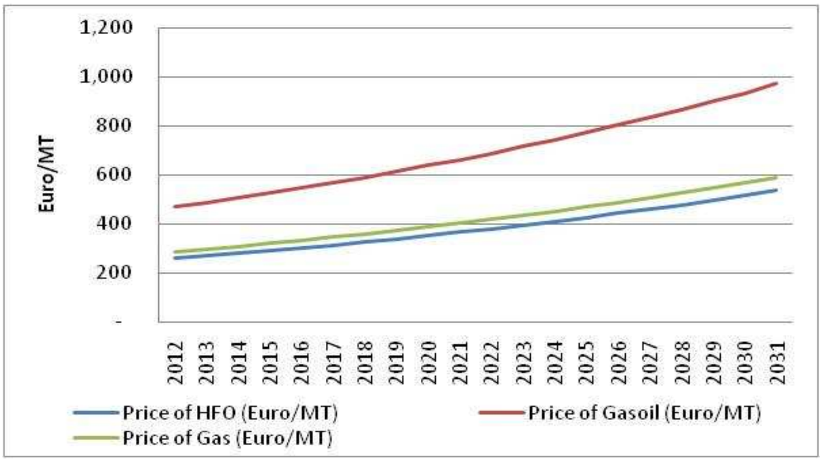
**Chart 4: Historical Trends in Crude Oil Prices**

(USD per barrel)




*Source: Bloomberg*

**Chart 5: Baseline Projections for Fuel Prices**




In terms of the development of the baseline scenario, it is assumed that the average price of crude oil will be rising by 4% per annum in real terms over the forecast horizon. This corresponds to the actual behaviour observed between 2000 and 2009, and serves as the basis for the growth in prices for each of the three fuel sources considered in this study. It is furthermore assumed that over the time period used for this analysis, the price of Gas will be 10% higher than that of HFO, while the price of Gasoil will be 81% higher than that of HFO. These assumptions reflect actual behaviour observed for the period 2000-

2009. The implications for the projected future prices of the three types of fuel considered in this study are illustrated in Chart 5.

These are assumptions extrapolated to the future over a 10-year past forecast horizon, and hence subject to an obviously high degree of uncertainty. Once again in this case it will be crucial to view the implications of these assumptions within the context of a sensitivity analysis.

Other operational cost elements and their modelling approach are detailed in Table 3. On the basis of the expected performance of the plant, Enemalta indicate that the cost of lubricant oil will in 2012 be, per metric tonne of fuel used, €7.71 in the case of HFO, and €8.09 in the case of Gasoil and Gas[4]. In subsequent years, they are modelled to grow *pari passu* with fuel expenditure, as the use of lubricant oil in volume terms would depend on the volume of fuel actually used, while its price will develop in line with the international price of crude. For the cost of urea, in the same spirit, Enemalta indicate that per tonne of fuel used, in 2012 it will be at €11.01 in the case of HFO and at €11.55 in the case of Gasoil and Gas[5]. The price of urea can be expected to remain stable in real terms while its use in quantity terms would depend on actual fuel use. Thus, the expenditure on this element is modelled to vary with the volume of fuel used.

**Table 3: Non-Fuel Cost Elements in Operational Costs**

| Variables | |
|---|---|
| Lubricant oil cost | Varies with Fuel Expenditure |
| Urea Cost | Varies with Volume of Fuel |
| Desox Reagent Cost | Annual growth of 2% |
| Maintenance Agreement | Fixed+Variable element which varies with electricity generated |
| Maintenance personnel | Fixed |
| Waste Disposal m3/MT | Varies with Volume of Fuel |
| Operational Personnel | Fixed |
| Electricity to plant | Varies according to Price of Fuel |
| Steam | Varies according to Price of Fuel |
| SCR Regeneration disposal | Incurred every fifth year based on average of fuel consmption in the previous five years |

In terms of the expenditure on Desox reagent, Enemalta indicate that the price element can be expected to develop in line with observations over recent months, and is thus modelled to grow by 2% per annum in real terms, while the quantity used would be stable. Thus, the expenditure on this product is modelled to grow by 2% per annum in real terms, from a 2012 base provided by Enemalta which feature an expenditure per tonne of fuel used of €13.99 in the case of HFO, and one-tenth of that amount in the

[4] In the case of Gas, 2012 figures relevant only to the extent that they serve as a basis for the estimation of the 2015 initial data.

[5] These cost parameters are narrowly specific to the plant to be utilized in DPSE and had therefore to be sourced directly from Enemalta.

case of Gasoil, as the use of the latter fuel requires far less use of the reagent . No Desox reagent is expected to be used in the case of Gas.

In terms of maintenance costs of DPSE, Enemalta have entered a maintenance agreement with third parties which involves a fixed element of expenditure and a variable element depending upon the output of the plant. The fixed element involves an expenditure of almost €1.6 million per annum. The variable element involves an expenditure of almost €3 per MWh produced. These parameters are set irrespective of the type of fuel used, and hence this element of expenditure would not impinge on the relative attractiveness of different fuels.

In the same manner, the cost of maintenance personnel, associated with Enemalta's employees, apportioned to the DPSE is invariant with the type of fuel used, and is assumed to remain constant in real terms at €589,000 per annum.

The cost of waste disposal is modeled to vary with the volume of fuel used. This from a basis of 2012 costs as indicated by Enemalta, which, per metric tonne of fuel used, amounts to €16.26 in the case of HFO and one-tenth of that amount in the case of Gasoil. No such costs are envisaged in terms of the use of Gas as fuel.

The costs associated with operational personnel are treated in the same manner as maintenance personnel, and held constant in real terms at €910,000 per annum, irrespective of the type of fuel used. Table 3 also details the modeling procedures adopted in the case of the relatively minor elements of electricity to plant, use of steam and SCR regeneration disposal. Taken together, these elements are expected to imply costs of around €100,000 per annum on an average basis.

An important consideration in this regard is that the costs of emissions trading are not considered in the financial model, mainly for these reasons:

- it is assumed that Enemalta will be respecting emissions limits and hence incurring no additional financial costs in this regard;
- from a methodological viewpoint, the costs of emissions are to be considered in the wider economic model whereby their socio-economic impact is evaluated using the shadow price approach – a financial approach towards modeling emissions costs, based, for instance, on the price of tradable emissions instruments, would very likely give a partial and unreliable estimates of the true socio-economic costs of emissions;
- it is very difficult to obtain reliable forecasts of the future financial costs of emissions, assuming that these would be relevant to the present study.

The approach taken here is therefore to consider emissions costs through the use of shadow prices in the study of the costs of externalities.

It is important to here reiterate the incremental approach taken with respect to the modeling of the Gas scenario. Because the Gas infrastructure would only be utilizable starting in 2015, costs for the period running from 2012 to 2014 were modeled on the basis of the use of the financially less expensive fuel.

From 2015 onwards, the total cost of using Gas in both the DPSE and the existing component of the Delimara Power Plant were considered, net of the cost of running the existing component on Gasoil.

### 3.3 Financial Modelling Results

On the basis of the approach discussed above, financial modeling for the three scenarios was undertaken over the 20-year horizon running to 2031. The results are here synthesized in terms of net present values using a time discount rate of 5%, as presented in Table 4. Detailed results of the financial model for the three scenarios are presented in Annex 2.

**Table 4: Summary Results of the Financial Model**

| Net Present Value of Costs (€) | |
|---|---|
| | Baseline |
| Scenario I (HFO+Gasoil) | 662,564,568 |
| Scenario II (Gasoil) | 997,352,398 |
| Scenario III (Gas) | 856,011,612 |
| | |
| Proportion of GDP | |
| Scenario I (HFO+Gasoil) | 0.5% |
| Scenario II (Gasoil) | 0.8% |
| Scenario III (Gas) | 0.7% |
| GDP (NPV) | 122,190,125,467 |

Table 4 indicates that the net present value of financial costs involved in Scenario I, which models the use of the financially more favourable fuel between HFO and Gasoil, which is effectively HFO, is €662.6 million. The Gasoil scenario is around 50% more expensive at almost €1 billion. The Gas scenario is also substantially more financially expensive than the HFO scenario, involving higher costs by a margin of around 29%. These net present value figures for costs can be scaled to a Gross Domestic Product (GDP) parameter, to capture the implications of differences in financial costs between the scenarios in terms of the burden relative to the output of the economy. Assuming an average real GDP growth of 2.5% during the forecast horizon, the cost of using HFO to fuel the DPSE would amount to 0.5% of GDP, that of using Gasoil would be 0.8% of GDP, and that of using Gas would absorb 0.7% of GDP.

In the above results, it is critical to note that the data for Gas represents the costs of producing electricity in both the existing element of the Delimara Power Plant as well as in the DPSE. An adjustment for this is made below through the estimation of the prime dynamic cost of electricity production.

The prime dynamic cost of electricity generation is an interesting metric to compare the three scenarios. This is reported in Table 5.

The prime dynamic cost is the total cost, investment and operational, of each of the fuel options in relation to the amount of electricity generated during the 20-year horizon of analysis. In other words, in is the average cost per MWh produced. Given the cost recovery formula currently being adopted by the Malta Resources Authority in the determination of tariff rates, this indicator would have a bearing on tariff levels in the economy.

**Table 5: Prime Dynamic Costs of Electricity Generation**

| Prime Dynamic Cost | Cost/MWh |
|---|---|
| HFO | 87.40 € |
| Gasoil | 131.56 € |
| Gas | 94.30 € |

The results shown in Table 5 show that electricity generation by Gas is, at a financial cost of €94.3/MWh, 7.9% more expensive than that by HFO, while generation through Gasoil, at a cost of €131.56/MWh, is 50.5% more expensive. Thus, by making the adjustment for the fact that Gas is being used to fuel the entire Delimara Power Plant, Gas still emerges as a more financially expensive alternative than HFO, even when considering the average cost per MWh produced. This is due to the fact that Gas, as a fuel, is presumed to have a price that is 10% more expensive than that of HFO. Furthermore, the use of Gas requires a significant initial investment cost. Mitigating these effects are the facts that Gas involves less expenses in certain elements of operational cost, such as waste management, and will also enable savings to be made through the replacement of Gasoil on the existing component of the power plant. Such savings however would be limited by the fact that the actual use of the existing plant after 2013 is likely to be relatively contained, as shown in the power generation plan illustrated in Chart 2.

Table 6 provides further explanation of the cost components underlying the net present value of cost results for the three scenarios.

**Table 6: Cost Components of the Scenarios**

| | HFO | Gasoil | Gas |
|---|---|---|---|
| Net Present Values for a 20-year period of operations (euro) | | | |
| **Investment Costs (Net of Residual Value)** | - | - | **223,949,834** |
| *Operational Costs* | | | |
| Fuel Cost | 521,368,130 | 899,272,477 | 452,160,237 |
| Lubricant oil cost | 15,497,799 | 15,491,457 | 11,430,519 |
| Urea Cost | 16,023,729 | 16,016,307 | 12,194,341 |
| Desox Reagent Cost | 23,916,568 | 2,279,117 | 0 |
| Maintenance Agreement | 42,196,154 | 42,196,154 | 32,081,582 |
| Maintenance personnel | 7,337,650 | 7,337,650 | 5,734,223 |
| Other Costs | 24,878,380 | 3,413,079 | 871,248 |
| Operational Personnel | 11,346,157 | 11,346,157 | 8,866,790 |
| 2012-2014 Operational Costs Under Gas Scenario | | | 133,707,550 |
| Net Savings from Using Gas on Existing Plant post 2015 | | | -24,866,081 |
| **Total Operational Costs** | **662,564,568** | **997,352,398** | **632,061,778** |
| **TOTAL COSTS** | **662,564,568** | **997,352,398** | **856,011,612** |

Table 6 indicates that in each of the three scenarios, the cost of fuel purchase is a major component of total costs, thereby explaining the bulk of the differences in the relative cost differentials between the three scenarios. In the Gas scenario, there is furthermore the element of initial investment cost net of its residual value, whereby the residual value is taken as the value of the remaining life of the investment infrastructure, which is estimated to amount to 10 years out of a total of 30 years. There is furthermore in this scenario, the complication that operations and maintenance costs start to impinge as from 2015, and partly for this reason shown to be lower than those in the other scenarios, but this is offset by the fact that in the initial years, the DPSE would be fuelled through HFO. There are furthermore the net savings of running the existing plant on Gas, starting as from 2015.

It can be therefore concluded that mainly on account of the purchase price of fuel, the scenario involving the use of HFO presents significant cost advantages, from a financial viewpoint, compared to the other scenarios.

## 4. The Estimation of Externality and Economic Costs

Externalities are effects on the welfare of society and the economy in general arising out of an economic activity for which no direct financial prices are paid. For the purposes of this study, the most relevant externality effects are those related to the costs of emissions from electricity production, within a situation where there are no mechanisms to internalize such costs within the financial costs of the activity itself. The total of financial and externality costs would then constitute the aggregate economic cost of an activity. This section provides estimates of the externality costs of emissions under the three scenarios, so as to derive the aggregate economic cost of each one of them.

The inherent difficulty with estimating externality effects is that there exist no suitable market prices to rely upon in conducting such estimations. Indeed, where they exist, such market prices would possibly give a distorted picture of the actual effects, as such prices would tend to capture individual effects which are internal to the parties within a transaction, and would not reflect wider social and economic effects. For this reason, shadow prices are used within the context of estimating externality effects.

### 4.1 Shadow Prices of Emissions

For the purposes of this study, the costs of emissions are estimated on the basis of shadow prices provided in *Handbook of Shadow Prices - Valuation and Weighting of Emissions and Environmental Impacts (2010)*[6]. In summary, the cost of emissions used in the study are based on the **damage cost method** whereby environmental quality is valued on the basis of the estimated damage occurring as a result of emissions and other changes in natural capital. The damage cost method proceeds from people's willingness to pay not to damage the environment and is commonly used by economists for assigning a value to externalities. The damage costs include all measurable negative effects that can be attributed to environmental pollution. These negative effects include direct impacts only, even though

[6] de Bruyn S., Kortland M., Markowska A., Davidson M., de Jonge F., Bies M., Sevenster M. (2010). *Handbook of Shadow Prices - Valuation and Weighting of Emissions and Environmental Impacts*, Delft.

there may also be indirect impacts. Values used in the study pertain to the average of the EU-27 countries.

In general terms, the impact of the emissions within the *Handbook* cover:

- human health (focusing on premature illness and death);
- ecosystem (based on restoration costs);
- impact on building and materials (loss of mechanical strength and materials degradation);
- impact on agricultural crops.

Table 7 details the emissions which are considered to be relevant for the purposes of this study and the way in which the shadow prices as derived in the *Handbook* cover the effects of such emissions. It is important to state that only emissions to air arising out of electricity production on a normal business-as-usual basis are considered here. Possible emissions arising out of waste management, or failings thereof, and from other accidents which are not considered to be part of the normal operations of the activity are not considered here, but are discussed in the section on risks and mitigants.

**Table 7: Relevant Emissions and their Treatment in Shadow Pricing**

| | Human Health | Ecosystems | Crops and Buildings |
|---|---|---|---|
| CO2 | * | * | |
| SO2 | * | * | * |
| NOX | * | * | * |
| PM2.5 | * | | |
| PM10 | * | | |
| Dust | * | | |
| Nh3 | * | * | * |
| Arsenic | * | | |
| Cadmium | * | | |

*Source: Handbook of Shadow Prices(2010)*

On these bases, the estimates for relevant emissions as reported in the Handbook of Shadow Prices are presented in Table 8.

**Table 8: Estimates for Shadow Prices of Relevant Emissions**

| Shadow Prices | |
|---|---|
| **Emission** | **Price of emissions Euro/kg pollutant (EU27)** |
| CO2 | 0.0265 |
| SO2 | 9.8 |
| NOX | 10.2 |
| PM2.5 | 35.8 |
| PM10 | 24.0 |
| Dust | 30.1 |
| Nh3 | 18.6 |
| Arsenic | 771.8 |
| Cadmium | 121.9 |

*Source: Handbook of Shadow Prices (2010) Table 16*

* Prices used in the economic model have been adjusted based based on euro area inflation rate and a predicted inflation rate of 2%.

The price of emissions as reported in Table 8 and which are effectively taken for the purposes of this study pertain to EU27. The price of emissions could be refined to take into consideration Malta's relative income to the EU average by taking into consideration Malta's GDP per capita in PPS as 81%. This approach would however detract from the advantages of fuels with lower emission values. Therefore, the approach adopted here may be erring in favour of the relative advantages of low-emission fuels.

It is furthermore important to clarify at the outset that any methodology aimed at the estimation of shadow price effects is subject to considerable estimation variations and critical assumptions. The monetary values of damages per unit of the specific pollutants presented in the *Handbook* are no exception to this rule. The estimates presented in the *Handbook* use a variety of assumptions and models. There is thus a degree of uncertainty in the value of the estimates, particularly with regards to the valuation of health damages and the wide variation in published estimates of dose-effect relationships and monetary valuation of impacts.

It is to be added that there are no scientifically exact methods to measure shadow prices of emissions[7]. Values of shadow prices may furthermore change over time in the light of shifting political, social, and economic priorities. However, an estimate of such prices must be included in this type of analysis, and this assessment is being undertaken using the best available estimates at present. Nevertheless, in view of the inherent uncertainties, it will be important to undertake a sensitivity assessment with respect to different values of shadow prices to gauge implications on the baseline results.

[7] This is attested, for example, by outcome of the ExterneE Project http://www.externe.info/ financed by the EU Commission.

4.2 Emissions Values and Costs

The aim of this section is to derive the net present values of the cost of emissions over a 20-year period of operation under the three fuel scenarios. Towards this end, the value of shadow prices per unit of emissions must be combined with the values of the emissions expected under each scenario for fuel use. This requires, in the first place, the establishment of the amount of emissions per type of pollutant as would be applicable under each of the three types of fuel. Information in this respect is provided in Table 9.

The Table provides, for each fuel source, the expected amount of emissions in terms of grams per KWh of electricity produced or per metric tonne of fuel used. Information is relevant for the DPSE equipment and also for the existing Delimara plant, in that under the Gas scenario, the implications for emissions of the switch of fuel from Gasoil to Gas from 2015 onwards would have to be taken into account. As expected, Gas has the best performance in terms of emissions minimization, followed by Gasoil, with HFO having the worst performance. There is thus an immediately apparent trade-off to be made between the low financial costs of using HFO and the relatively high costs of emissions which this would entail.

The information presented in Table 9 was sourced from Enemalta, on the understanding that emissions values are subject to the specific characteristics and operating conditions of the power plant.

**Table 9: Emissions Values**

| Emissions from Delimara Extension | | | | |
|---|---|---|---|---|
| | **Gas** | **HFO** | **Gasoil** | **Unit** |
| CO2 | 415 | 576 | 551 | g/KWh |
| SO2 | nil* | 0.73 | 0.365 | g/kWh |
| NOX | 0.49** | 0.97 | 0.97 | g/kWh |
| Dust*** | 0.09 | 0.33 | 0.198 | g/kWh |
| Nh3 | | 101 | | g/MT |
| Arsenic | | 0.0005555 | | g/kWh |
| Cadmium | | 0.0000257 | | g/kWh |
| * It is assumed that there is no sulfur content in the gas fuel. | | | | |
| ** There are conflicting figures regarding the emissions on NOX from gas fired diesel engine plant with Best Reference document quoting a range from 0.13g/kWh to 0.49g/kWh as translated to our plant. However, other sources in the same document also state a higher figure of 0.97g/kWh. | | | | |
| *** The figures available between the three fuels are only for dust. Such figures do not discriminate between PM2.5 and PM10. The price of dust emissions has been taken as the relative Predicted Environmental Concentration of PM10 and PM2.5 noted in the EIA required for the planning extension of the Delimara Power Station. | | | | |
| **Emissions from Delimara Existing** | | | | |
| | **Gas** | **HFO** | **Gasoil** | **Unit** |
| CO2 | 498 | N/A | 658 | g/KWh |
| SO2 | nil* | N/A | 0.134 | g/kWh |
| NOX | 0.102 | N/A | 1.41 | g/kWh |
| Dust | 0 | N/A | 0.0051 | g/kWh |
| Nh3 | 0 | N/A | 0 | g/MT |
| Arsenic | 0 | N/A | 0 | g/kWh |
| Cadmium | 0 | N/A | 0 | g/kWh |

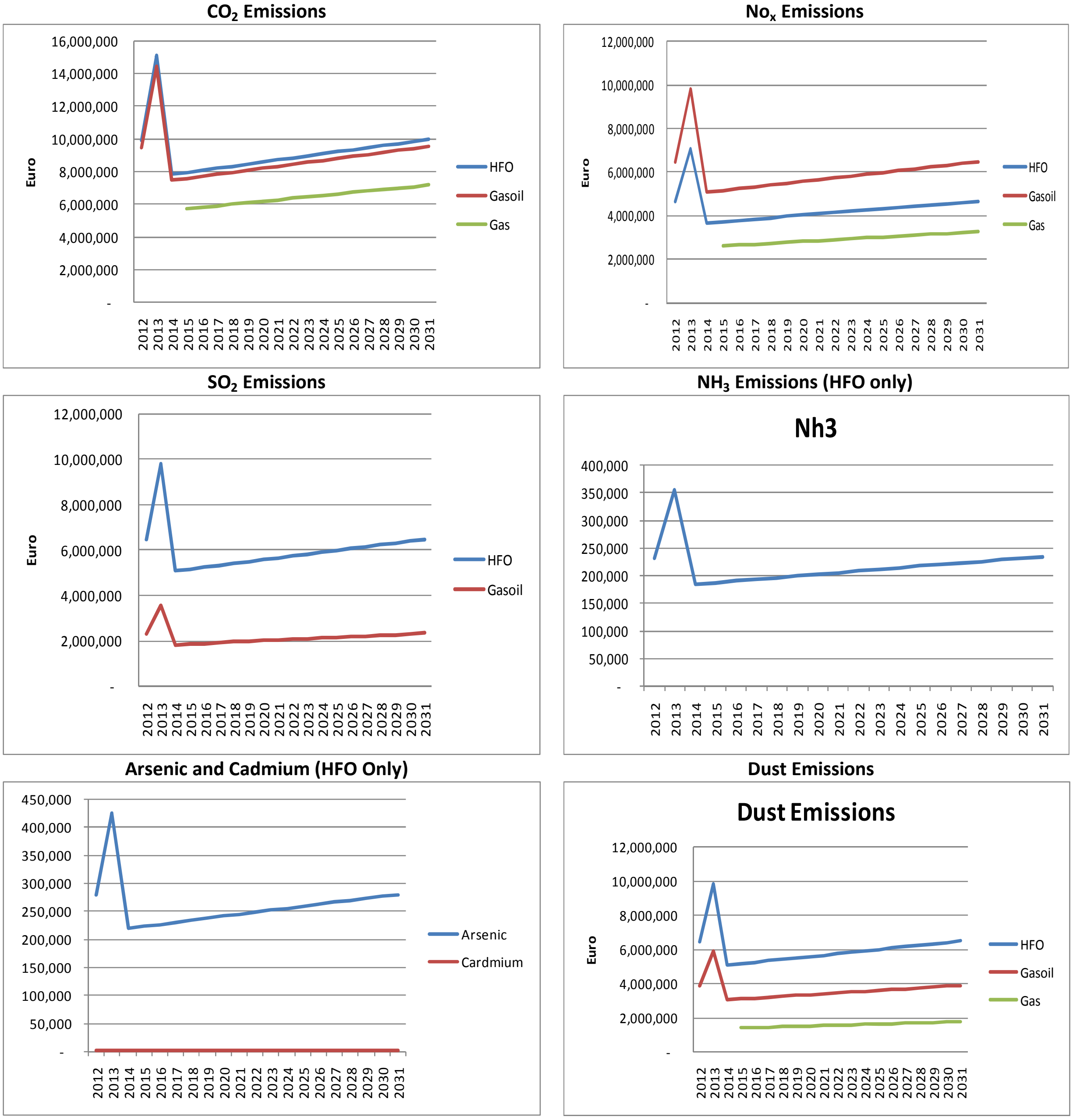
*Source: Enemalta. Emissions values for DPSE were sourced from tender bidding documents and the application of IPCC and BREF2006 formulae to the extension plant. Emissions values for the existing plant were sourced from the application of IPCC formulae and LCP emission limits.*

Combining the above emissions values, with the annual projections in power generation and fuel use for the DPSE (and for the Gas Option, the existing Plant), together with the shadow price values reported in Table 8, the values for the costs of emissions per pollutant per year under each of the three scenarios is obtained. This information is presented in Chart Panel 6. The most significant elements in terms of pollution costs as emerging from this analysis are $CO_2$, $No_x$ and Dust emissions, with an important impact also emanating from $SO_2$.

The total emissions costs are expected to vary significant by type of fuel. In the case of HFO, these are estimated at an average of €26.1 million per year for the 20-year period of analysis considered in this study. In the case of Gasoil, the comparable figure would be €20.7 million per year. For the scenario where the Gas fuel is used, the total cost of emissions is estimated at €14 million per year.

The next step in the analysis is to combine these emissions costs with the financial costs to derive a total aggregate economic analysis of the costs inherent in the use of different types of fuel.

**Chart Panel 6: Annual Costs of Emissions**




## 4.3 Aggregate Economic Costs

The financial and emissions costs analysis is aggregated to produce the total economic costs inherent in the three scenarios. This information is presented in summary form in Table 10, which shows net present values of costs for the three scenarios for a 20-year period of operation. A discount rate of 5.5% is used, in line with the recommendations for the discounting of economic variables which can be found in the *Guidelines for Cost-Benefit Assessments for Cohesion and ERDF Funding*[8]. Annex 3 presents the full details of all the cost components inherent in the aggregate economic cost analysis.

**Table 10: Aggregate Economic Costs[9]**

| | Total Costs | Emissions Costs | Financial Costs |
|---|---|---|---|
| Scenario I (HFO+Gasoil) | 945,628,116 | 313,254,934 | 632,373,182 |
| Scenario II (Gasoil) | 1,199,118,887 | 247,738,127 | 951,380,759 |
| Scenario III (Gas) | 1,007,542,056 | 180,007,321 | 827,534,734 |

The conclusion of this analysis is that Scenarios I and III present, on aggregate, quite similar levels of costs, with Scenario I involving the use of HFO, showing some advantages over the other on account of its financial performance. Gas has the lowest costs from an emissions perspective, but this is not sufficient to outweigh its financial disadvantage compared to HFO in terms of aggregate cost performance. Thus, on the basis of this analysis, the aggregate cost of the Gas scenario, at just over €1bn in terms of net present value over a 20-year horizon, is found to be 6.5% more expensive than the scenario involving the use of HFO. Gasoil, on the other hand, has a poor financial performance and an intermediate emissions performance, and emerges on aggregate to be almost 27% more expensive than the lowest cost scenario.

## 5. Sensitivity Analyses

Earlier on in this report, there have been several instances where significant uncertainties in parameter estimation or modelling approach were noted. Moreover, the aggregate results for economic costs obtained indicate relatively marginal differences between the scenarios involving the use of HFO and that involving Gas. It is for these reasons important to conduct a sensitivity analysis to ascertain the extent to which the result obtained would change under different operating conditions from those specified in the baseline model discussed so far. In order to capture the essential aspects in this regard, this section presents eight different scenarios to conduct the sensitivity assessments involving:

- demand for electricity increasing by 1% per annum rather than the 0.5% assumed in the baseline model;
- demand for electricity remaining flat for the period of analysis;
- the price of crude oil rising by 10% per annum in real terms rather than the 4% assumed in the baseline model;
- the relativity between the price of Gasoil and that of HFO widening by 50%;
- the relativity between the price of Gas and that of HFO widening by 50%;
- the investment cost in the Gas infrastructure rising by 10%;
- the shadow prices of emissions rising by 10%;

[8] The use of this discount rate value, as opposed to the 5% rate in the financial analysis, explains the marginal difference in the net present value of financial costs shown in Table 10 and those shown in Table 4.
[9] Financial Costs presented in Table 10 do not tally with costs presented in Table 4 due to the different discounting rate used in the financial and economic assessment.

- a higher load of electricity demand being satisfied through interconnection facilities from 2020 onwards.

The results of these sensitivity assessments are reported in terms of their effects on the net present values of the financial and economic costs under the three scenarios for different fuel use. Where relevant, switching values associated with the sensitivity assessments are also identified. These are the values of the parameters that are being changed in a sensitivity assessment at which the relative preference ranking of the different scenarios would change.

Table 11 details the results of the scenario where demand for electricity supplied by Enemalta increases by 1% rather than by 0.5% per annum. Such a situation could occur either because of a genuine increase in demand, reduced energy efficiency or because the economy makes less use of alternative sources of energy. As can be expected, all scenarios for fuel use would feature higher financial and aggregate economic costs. Costs would rise more for the HFO and Gasoil scenarios than for the Gas scenario, due to the fact that the first two scenarios feature a higher proportion of fuel within their financial costs, and have higher emission values compared to Gas. Indeed, in this situation, it is shown that from an economic cost perspective, the HFO and Gas scenarios are almost equivalent. Thus, an increase in demand of 1% per annum would constitute a switching value whereby the use of Gas would be equally preferred, from an aggregate economic viewpoint, to that of HFO. In other words, the use of Gas would become attractive if the economy and society do not behave in a manner which is more conducive to energy conservation and use of renewable sources.

**Table 11: Sensitivity to Higher Growth in Electricity Demand**

| | Baseline: Demand increasing by 0.5% per annum | | Scenario: Demand increase by 1% | | Percentage Change | |
|---|---|---|---|---|---|---|
| | Financial | Economic | Financial | Economic | Financial | Economic |
| Scenario I (HFO+Gasoil) | 662,564,568 | 945,628,116 | 748,880,956 | 1,064,258,887 | 13.03% | 12.55% |
| Scenario II (Gasoil) | 997,352,398 | 1,199,118,887 | 1,131,378,921 | 1,354,583,043 | 13.44% | 12.96% |
| Scenario III (Gas) | 856,011,612 | 1,007,542,056 | 920,882,690 | 1,080,314,671 | 7.58% | 7.22% |

| Prime Dynamic Cost | Cost/MWh | % increase from Baseline |
|---|---|---|
| HFO | 87.99 € | 0.68% |
| Gasoil | 132.93 € | 1.05% |
| Gas | 88.74 € | -5.90% |

From a financial cost perspective, however, the HFO scenario remains preferable. On the other hand, if demand growth rate were to double from 0.5% to 1% p.a., the Gas option would approximate the HFO option viewed from a prime dynamic cost perspective. This is because of the relatively high fixed capital content in the Gas option expenditure, whereby it would become more viable if it is spread over a larger number of MWh produced.

Opposite results would be obtained if demand for electricity were to grow at a slower rate. A situation of zero demand growth for electricity supplied by Enemalta would result in significantly lower costs in the HFO but to a lower extent in the use of Gas, as shown in Table 12. This would also produce a wider differential in terms of prime dynamic cost, between the use of HFO and Gas. Thus, the use of HFO would become increasingly preferable in a situation where there is a lower demand for energy supplied by Enemalta.

**Table 12: Sensitivity to No Growth in Electricity Demand**

| | Baseline: Demand increasing by 0.5% per annum | | Scenario: Flat Demand | | Percentage Change | |
|---|---|---|---|---|---|---|
| | Financial | Economic | Financial | Economic | Financial | Economic |
| Scenario I (HFO+Gasoil) | 662,564,568 | 945,628,116 | 574,249,883 | 823,735,384 | -13.33% | -12.89% |
| Scenario II (Gasoil) | 997,352,398 | 1,199,118,887 | 860,270,634 | 1,039,648,580 | -13.74% | -13.30% |
| Scenario III (Gas) | 856,011,612 | 1,007,542,056 | 776,663,394 | 917,227,458 | -9.27% | -8.96% |

| Prime Dynamic Cost | Cost/MWh | % increase from baseline |
|---|---|---|
| HFO | 86.75 € | -0.74% |
| Gasoil | 129.96 € | -1.21% |
| Gas | 97.53 € | 3.42% |

Table 13 presents the results of a sensitivity assessment with respect to higher crude oil prices. As expected, the costs of all scenarios would increase, but under the Gas scenario, such increase would take place at a slower rate due to its lower fuel cost element within its total cost profile. It is however found that there needs to be an increase in the price of oil of over 60%, as compared to its expected baseline development, to create anequivalent cost between the use of HFO and Gas.

**Table 13: Sensitivity to Higher Crude Oil Prices**

| | Baseline: Price of Crude Oil increasing by 4% | | Scenario: Price of Crude Oil increasing by 10% | | Percentage Change | |
|---|---|---|---|---|---|---|
| | Financial | Economic | Financial | Economic | Financial | Economic |
| Scenario I (HFO+Gasoil) | 662,564,568 | 945,628,116 | 1,084,264,538 | 1,339,049,758 | 63.65% | 41.60% |
| Scenario II (Gasoil) | 997,352,398 | 1,199,118,887 | 1,715,239,374 | 1,868,865,264 | 71.98% | 55.85% |
| Scenario III (Gas) | 856,011,612 | 1,007,542,056 | 1,285,307,549 | 1,408,079,814 | 50.15% | 39.75% |

| | Financial | Economic |
|---|---|---|
| Baseline value | Price of Crude Oil increases by 4% per annum | |
| Switching value | Relative Price of 1.625 | Relative price of 1.64 |
| Notes: | Gas has a high fixed cost element. A substantial increase in the price of crude oil is needed to make it financially preferable. Also, a 64% increase per annum in the price of crude oil would erode the economic advantages of the gas option. To be noted that when the price of crude oil increases, the price of gas also increases. | |

Table 14 shows the results of a sensitivity assessment whereby the differential between the price of Gasoil and that of HFO is increased by 50%. This impacts on the Gasoil results substantially negatively, and marginally improves the results for Gas, given that the latter fuel is modelled to replace the higher priced Gasoil in Scenario III in the existing component of the power plant from 2015 onwards. There are however no reasonable expectations that a shock of this kind would render the Gas option equally preferred to the use of HFO, either from the financial or from the entire economic perspectives.

**Table 14: Sensitivity to Increase in Gasoil Price Relative to HFO**

| | Baseline: Relative Price of Gasoil to HFO: 1.81 | | Scenario: Relative Price of Gasoil to HFO increases by 50% to 2.7 | | Percentage Change | |
|---|---|---|---|---|---|---|
| | Financial | Economic | Financial | Economic | Financial | Economic |
| Scenario I (HFO+Gasoil) | 662,564,568 | 945,628,116 | 662,564,568 | 945,628,116 | 0.00% | 0.00% |
| Scenario II (Gasoil) | 997,352,398 | 1,199,118,887 | 1,439,536,103 | 1,620,715,048 | 44.34% | 35.16% |
| Scenario III (Gas) | 856,011,612 | 1,007,542,056 | 833,982,352 | 986,851,445 | -2.57% | -2.05% |
| | Financial | | | Economic | | |
| Baseline value | Relative Price of Gasoil to HFO increases by 50% to 2.7 | | | | | |
| Switching value | Relative Price of 9.6 | | | Relative price of 4.5 | | |
| Notes: | Relative price of Gasoil to HFO would have to increase substantially for the financial feasibiltiy of Gas to match that of HFO. This is due to the fact that elements of Gas operations are fixed to Gasoil. In terms of the economic feasibility, the relative price of Gasoil to HFO woud need to increase more than four times , for HFO to lose its economic advantageous position. | | | | | |

Table 15 presents modelling results for an increase in the price of Gas relative to HFO by 50 percentage points, with the differential between the price of Gas and that of HFO thereby rising from 10% to 65%. This would increase the financial cost of Gas use by 28.1%, and its economic cost by 22.5%. It is further shown that for Gas to be equally preferable to HFO from a financial perspective, its price would have to be 66% that of HFO, mainly to offset the investment costs associated with the Gas option. From an aggregate economic perspective, however, taking into account the costs of emissions, the price of Gas would have to be equal to 95% that of HFO for the Gas option to become equally preferred to the HFO use option.

**Table 15: Sensitivity to Increase in Gasoil Price Relative to HFO**

| | Baseline: Relative Price of Gas to HFO: 1.1 | | Scenario: Relative Price of Gas to HFO increases by 50% to 1.65 | | Percentage Change | |
|---|---|---|---|---|---|---|
| | Financial | Economic | Financial | Economic | Financial | Economic |
| Scenario I (HFO+Gasoil) | 662,564,568 | 945,628,116 | 662,564,568 | 945,628,116 | 0.00% | 0.00% |
| Scenario II (Gasoil) | 997,352,398 | 1,199,118,887 | 997,352,398 | 1,199,118,887 | 0.00% | 0.00% |
| Scenario III (Gas) | 856,011,612 | 1,007,542,056 | 1,096,353,584 | 1,234,463,167 | 28.08% | 22.52% |
| | Financial | | | Economic | | |
| Baseline value | Relative Price of Gas to HFO increases by 50% to 1.65 | | | | | |
| Switching value | Relative price of 0.66 | | | Relative price of 0.95 | | |
| Notes: | Price of gas would have to be 34% lower than HFO for the gas option to be as financialy feasible as HFO. Also, price of gas would have to be 5% lower than HFO for the option to be as economically advantageous as HFO. | | | | | |

The sensitivity analysis to changes in investment costs in the Gas use scenario is presented in Table 16. A 10% increase in such investment costs would deteriorate the net present value of the cost of using the Gas fuel by 2.6% from a financial perspective, and by 2.2% from an economic perspective. It is furthermore indicated that for the use of Gas to be equally preferred to that of HFO from a financial perspective, investment costs in Gas would have to drop by 86%. On the other hand, for Gas to be on a par preference with HFO from an economic perspective, such investment costs would have to be 26% lower than those set in the baseline model.

**Table 16: Sensitivity to Increase in Gas Investment Costs**

| | Baseline: Investment Cost | | Scenario: A 10% increase in the investment cost of Gas | | Percentage Change | |
|---|---|---|---|---|---|---|
| | Financial | Economic | Financial | Economic | Financial | Economic |
| Scenario I (HFO+Gasoil) | 662,564,568 | 945,628,116 | 662,564,568 | 945,628,116 | 0.00% | 0.00% |
| Scenario II (Gasoil) | 997,352,398 | 1,199,118,887 | 997,352,398 | 1,199,118,887 | 0.00% | 0.00% |
| Scenario III (Gas) | 856,011,612 | 1,007,542,056 | 878,406,596 | 1,029,946,347 | 2.62% | 2.22% |
| | Financial | | | Economic | | |
| Baseline value | Investment Cost of Euro 297.621 million | | | | | |
| Switching value | Investment Cost lower by 86% | | | Investment cost lower by 26% | | |

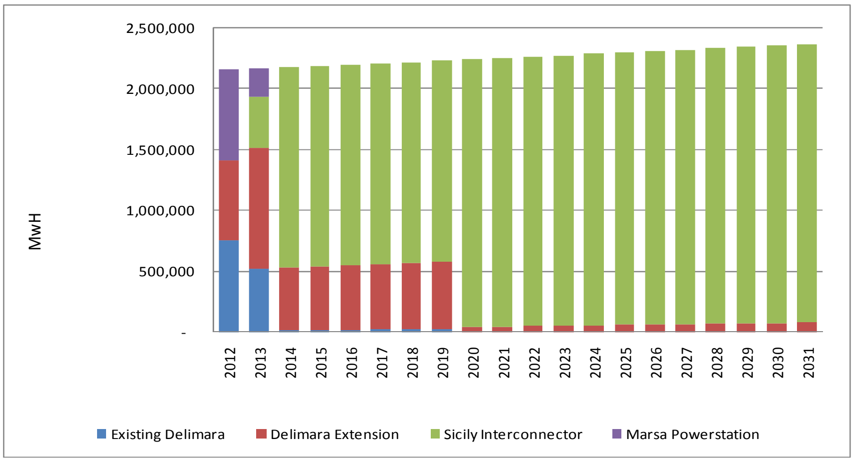
Table 17 presents the implications of a 10% increase in the shadow prices of all emissions. This could be occasioned, for example, through a higher social priority ranking of environmental concerns. This would of course leave all financial results unaffected, while increasing the economic costs of the HFO use scenario by 3.3%, compared to 1.8% which would take place in the Gas scenario. It is furthermore indicated that the shadow price of emissions must be 46% higher than that used in the baseline scenario for the Gas option to be equally preferred to the HFO option from an aggregate economic perspective.

**Table 17: Sensitivity to Higher Shadow Prices of Emissions**

| | Baseline Price of Emissions | | Scenario: A 10% increase in the price of all emissions | | Percentage Change | |
|---|---|---|---|---|---|---|
| | Financial | Economic | Financial | Economic | Financial | Economic |
| Scenario I (HFO+Gasoil) | 662,564,568 | 945,628,116 | 662,564,568 | 976,953,609 | 0.00% | 3.31% |
| Scenario II (Gasoil) | 997,352,398 | 1,199,118,887 | 997,352,398 | 1,223,892,699 | 0.00% | 2.07% |
| Scenario III (Gas) | 856,011,612 | 1,007,542,056 | 856,011,612 | 1,025,542,788 | 0.00% | 1.79% |
| | Financial | | | Economic | | |
| Baseline value | Baseline Price of Emissions | | | | | |
| Switching value | NA | | | Price of emissions increases by 46% | | |
| Notes: | The price of emissions must increase by 46% for HFO to lose its economically advantageous poosition compared to Gas. | | | | | |

Finally, Chart 7 presents the implications of an almost complete reliance on interconnection facilities for Enemalta to supply energy as from 2020. This may be occasioned by economic and financial considerations, as well as by regulatory issues concerning emissions and technology use in future. This scenario of reduced demand for local energy generation would put the Gas option at a disadvantage in view of its relatively high investment costs, with the other options being more favourable in the light of reduced fuel use and consequent emissions whic-h would take place in such a situation.

**Chart 7: Sensitivity to Use of Interconnector Facility**




| Prime Dynamic Cost | Cost/MWh | % increase from baseline |
|---|---|---|
| HFO | 80.57 € | -7.81% |
| Gasoil | 117.51 € | -10.68% |
| Gas | 99.26 € | 5.26% |

It is thus concluded, in general terms that while in the baseline scenario, HFO is significantly more favourable than Gas from a financial perspective, and presents a marginal advantage from an economic perspective, this relative ranking may be susceptible mainly to:

- the intensity of use of locally generated sources, whereby the greater the demand for locally-produced energy from conventional sources, the lower the relative advantage of HFO would be;
- variations in the prices of the individual fuels themselves;
- societal prioritisation with respect to environmental and health concerns.

## 6. A Note on Risk Considerations

For the sake of completion of the arguments presented in this report, the possible risks involved in the exceptional and unexpected events for Enemalta and for the economy associated with the use of different types of fuel are considered. The brief comments presented here are based on a review of a *Risk Assessment Technical Report on the Delimara Power Station extension (October 2009)* prepared for Enemalta.

The report sought to identify and assess risks from potentially hazardous materials such as fuels, chemicals and wastes from the construction and operation of the power station extension. It excludes risks from already existing processes or non-environmental safety issues like electrical safety or fire and explosion. The report focuses on the DPSE whereby a risk assessment is undertaken on a 144MW diesel engine combined cycle (DECC) plant consisting of medium speed diesel engines capable of burning HFO and Gasoil. No considerations are made on the utilization of Gas. It is here considered that this issue falls outside the objective of this report, in that the potential utilization of Gas, which can only start beyond 2015, would fall outside the purview of the current application for the IPPC. It is important however to note that the Gas option would not be devoid of risks, and these must be studied closely in any future application involving this type of fuel.

Potentially the most significant risks identified in the report:

- spillage during quayside oil offloading and transfer;
- catastrophic incident such as fire and loss of containment with application of substantial quantities of firewater, wherein the likelihood of such an incident is very small and current measures for control are considered to be generally appropriate to the risk;
- the handling and use of bulk chemicals and residues and the design and operation of the Effluent Treatment Plant.

Further details on these issues are provided in Annex 4.

It is to be noted that these risks already exist on the Existing Delimara Plant. However given that the footprint due to the extension is larger and given the fact that there will be additional plant and equipment the possibility of incidents with their associated risks may increase.

The report concludes that the risk assessment indicates that with the mitigation measures that the development has or proposes to have in place, the environmental risks are acceptable or tolerable. On this basis, this study finds no reason to consider such risks as being influential on the relative desirability of fuel options.

It may however be commented that from a wider economic perspective, it is important to ensure that emissions are kept within the expected limits. Therefore, an assessment of the risks associated with emissions is also warranted particularly in terms of the SCR emission abatement equipment.

## 7. Conclusions

On the basis of the analysis and discussion presented in this report, the following conclusions may be reached. In a baseline model which was founded on reasonable, but potentially varying, expectations about the future, the use of HFO to fuel the DPSE is found to be significantly more advantageous from a financial viewpoint and marginally more advantageous from an economic viewpoint. The next best option is Gas.

The financial advantage of HFO is robust to sensitivity assessments and actually improves significantly in the wake of energy efficiency in consumption, the utilisation of alternative energy sources and an increased reliance on inter-connection facilities. The economic advantage of HFO relative to Gas may be eroded by any one of the following conditions (everything else remaining the same):

- a 1% per annum increase in electricity demand;
- a 64% annual increase in crude oil prices;
- the relative price of gas to HFO declining from 110% to 95%;

- the investment in gas infrastructure being cheaper by 26%;
- a 46% increase in the shadow price of emissions.

In the circumstances, a policy of flexibility in terms of the ability to use different types of fuel is advisable. This is especially in the light of the fact that the DPSE is projected to generate around 25% of Malta's energy requirements over the next twenty years, and will be required to supply energy for 85% of the time during a typical year. Its efficient operation will therefore be critical to the country's energy performance, from the financial and economic viewpoints.

It is furthermore to be considered that the operation and context of the energy market will be subject to important dynamics over the period, affecting conditions such as:

- prices of fuels, in absolute and relative terms;
- values placed on emissions, depending also upon political, economic and social priorities;
- the growth in the demand for electricity produced and/or supplied by Enemalta;
- costs of investments in Gas and other infrastructures;
- the availability and feasibility of the use of different energy production technologies in future.

All of these factors are bound to have a significant impact on the country's energy performance. This also implies that there can be no single unequivocal answer as to the cheapest cost solution regarding the type of fuel which the country should be utilising over the forthcoming 20-year period. It will therefore be essential for the country to be in a position to choose between different types of energy sources from time to time, and not necessarily to commit to any single source for a protracted period. At the same time, it will be essential for such technology to be operated in the most efficient manner possible, to optimise financial and economic performance and minimise any attendant risks.

**Annex 1: An Overview of Options for the Development of Gas Importation Infrastructure**

Enemalta has considered three alternative approaches towards possibility of the development of infrastructure for the importation of Gas, namely:

- the use of Liquified Natural Gas (LNG), which would require the construction of a shore-based storage and gasification plant, whose investment cost is estimated at *circa* USD140 million, and the purchase of two small-sized custom-built ships at a cost of around USD70 million each, for a total cost of circa USD280 million;
- the use of compressed natural gas (CNG), which would need shore-based infrastructure at an investment cost of USD100 million to USD120 million and the acquisition of four ships estimated to cost between USD70 million and USD75 million each, for a total cost of between USD380 million and USD420 million;
- the development of a pipeline infrastructure linking Malta to Southern Europe, at a cost of *circa* USD320 million.

It is at this stage assumed, on the bases of preliminary indications provided by Enemalta, that the best approach is to develop the pipeline infrastructure. Enemalta has arrived to this conclusion on the basis of high-level considerations regarding:

- the fact that LNG and CNG infrastructures, particularly those related to the shipping elements, would be likely to have a useful life of around 20 years, whereas the gas pipeline would have a useful life of around 30 years – viewed in this manner, the pipeline option would have a residual value of around USD106 million, implying a net investment cost over the 20-year horizon of *circa* USD214 million;
- operational and maintenance costs in the solutions involving shipping are likely to be higher than those of the pipeline;
- land utilisation is likely to be less intense in the case of the use of the pipeline infrastructure – it is appreciated that the shore infrastructure for the CNG and LNG options would use the area already being allocated to the power plant;
- the complexity of shipping operations and attendant economic, financial and environmental risks, particularly those related to on-shore storage facilities within a densely populated territory, would not be present to the same extent under the pipeline approach.

Contrasting these elements would be the fact that the pipeline infrastructure would possibly limit diversification opportunities for the sourcing of fuel from a geographical market perspective, in that such infrastructure would be tied to a particular geographical location. This consideration, however, is not deemed to outweigh the advantages listed above.

# Annex 2: Detailed Results of the Financial Model

## Extension on HFO

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Operational and Maintenance** | | | | | | | | | | | | | | | | | | | | |
| Fuel Costs (HFO) | 32,204,684 | 50,970,820 | 27,628,561 | 29,099,782 | 30,749,858 | 32,414,964 | 34,195,017 | 36,081,498 | 38,089,250 | 40,115,818 | 42,246,375 | 44,593,818 | 46,942,306 | 49,441,612 | 52,102,059 | 54,819,026 | 57,645,080 | 60,622,696 | 63,811,351 | 67,146,404 |
| Lubricant oil cost | 957,292 | 1,515,120 | 821,266 | 864,998 | 914,047 | 963,543 | 1,016,455 | 1,072,532 | 1,132,213 | 1,192,453 | 1,255,784 | 1,325,562 | 1,395,372 | 1,469,664 | 1,548,747 | 1,629,509 | 1,713,514 | 1,802,025 | 1,896,808 | 1,995,944 |
| Urea Cost | 1,366,320 | 2,081,535 | 1,086,049 | 1,101,057 | 1,119,933 | 1,136,379 | 1,153,904 | 1,171,980 | 1,190,877 | 1,207,283 | 1,223,804 | 1,243,443 | 1,259,925 | 1,277,326 | 1,295,666 | 1,312,195 | 1,328,184 | 1,344,498 | 1,362,234 | 1,379,766 |
| Desox Reagent Cost | 1,736,132 | 2,697,828 | 1,435,754 | 1,484,707 | 1,540,363 | 1,594,243 | 1,651,205 | 1,710,613 | 1,772,959 | 1,833,332 | 1,895,588 | 1,964,528 | 2,030,379 | 2,099,590 | 2,172,330 | 2,244,043 | 2,316,815 | 2,392,177 | 2,472,209 | 2,554,107 |
| Maintenance Agreement | 3,508,554 | 4,512,683 | 3,102,383 | 3,123,718 | 3,150,287 | 3,174,320 | 3,198,903 | 3,224,485 | 3,251,163 | 3,274,134 | 3,297,400 | 3,324,995 | 3,348,354 | 3,372,884 | 3,398,636 | 3,421,910 | 3,444,849 | 3,467,783 | 3,492,858 | 3,517,734 |
| Maintenance personnel | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 |
| Waste Disposal | 2,017,708 | 3,073,900 | 1,603,819 | 1,625,982 | 1,653,857 | 1,678,144 | 1,704,023 | 1,730,718 | 1,758,624 | 1,782,851 | 1,807,248 | 1,836,251 | 1,860,590 | 1,886,287 | 1,913,370 | 1,937,779 | 1,961,391 | 1,985,482 | 2,011,674 | 2,037,565 |
| Operational Personnel | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 |
| Electricity to plant | 38,755 | 40,262 | 41,828 | 43,455 | 45,145 | 46,901 | 48,725 | 50,620 | 52,589 | 54,635 | 56,760 | 58,967 | 61,261 | 63,643 | 66,119 | 68,690 | 71,362 | 74,137 | 77,021 | 80,016 |
| Steam | 25,508 | 26,500 | 27,531 | 28,601 | 29,714 | 30,869 | 32,070 | 33,317 | 34,613 | 35,960 | 37,358 | 38,811 | 40,321 | 41,889 | 43,518 | 45,211 | 46,969 | 48,796 | 50,694 | 52,665 |
| SCR Regeneration disposal | - | - | - | - | - | 63,586 | - | - | - | | 55,166 | - | - | - | - | 59,305 | - | - | - | |
| **Total Operations and Maintenance Costs** | 43,354,190 | 66,417,886 | 37,246,428 | 38,871,537 | 40,702,442 | 42,602,187 | 44,499,540 | 46,575,000 | 48,781,525 | 50,995,703 | 53,374,720 | 55,885,613 | 58,437,744 | 61,152,132 | 64,039,681 | 67,036,905 | 70,027,400 | 73,236,832 | 76,674,086 | 80,263,438 |
| Min operations and Maintenance Costs | 43,354,190 | 66,417,886 | 37,246,428 | 38,871,537 | 40,702,442 | 42,602,187 | 44,499,540 | 46,575,000 | 48,781,525 | 50,995,703 | 53,374,720 | 55,885,613 | 58,437,744 | 61,152,132 | 64,039,681 | 67,036,905 | 70,027,400 | 73,236,832 | 76,674,086 | 80,263,438 |
| **Total Costs** | 43,354,190 | 66,417,886 | 37,246,428 | 38,871,537 | 40,702,442 | 42,602,187 | 44,499,540 | 46,575,000 | 48,781,525 | 50,995,703 | 53,374,720 | 55,885,613 | 58,437,744 | 61,152,132 | 64,039,681 | 67,036,905 | 70,027,400 | 73,236,832 | 76,674,086 | 80,263,438 |
| NPV | £662,564,568 | | | | | | | | | | | | | | | | | | | |

## Extension on Gasoil

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Operational and Maintenance** | | | | | | | | | | | | | | | | | | | | |
| Fuel Costs (Gasoil) | 55,543,807 | 87,911,299 | 47,656,018 | 50,193,550 | 53,039,651 | 55,911,272 | 58,981,586 | 62,235,358 | 65,698,322 | 69,193,850 | 72,868,668 | 76,917,599 | 80,968,215 | 85,279,029 | 89,867,838 | 94,554,094 | 99,428,204 | 104,564,041 | 110,063,768 | 115,815,924 |
| Lubricant oil cost | 956,834 | 1,514,418 | 820,954 | 864,667 | 913,696 | 963,164 | 1,016,055 | 1,072,107 | 1,131,762 | 1,191,979 | 1,255,283 | 1,325,033 | 1,394,812 | 1,469,072.41 | 1,548,122.24 | 1,628,850.75 | 1,712,815.36 | 1,801,288.65 | 1,896,030.55 | 1,995,120.97 |
| Urea Cost | 1,365,595 | 2,080,462 | 1,085,580 | 1,100,578 | 1,119,444 | 1,135,874 | 1,153,390 | 1,171,456 | 1,190,342 | 1,206,741 | 1,223,253 | 1,242,882 | 1,259,354 | 1,276,746 | 1,295,076 | 1,311,597 | 1,327,573 | 1,343,879 | 1,361,605 | 1,379,126 |
| Desox Reagent Cost | 165,432 | 257,074 | 136,824 | 141,488 | 146,792 | 151,925 | 157,353 | 163,014 | 168,955 | 174,709 | 180,641 | 187,211 | 193,486 | 200,081 | 207,013 | 213,846 | 220,780 | 227,962 | 235,588 | 243,392 |
| Maintenance Agreement | 3,508,554 | 4,512,683 | 3,102,383 | 3,123,718 | 3,150,287 | 3,174,320 | 3,198,903 | 3,224,485 | 3,251,163 | 3,274,134 | 3,297,400 | 3,324,995 | 3,348,354 | 3,372,884 | 3,398,636 | 3,421,910 | 3,444,849 | 3,467,783 | 3,492,858 | 3,517,734 |
| Maintenance personnel | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 |
| Waste Disposal | 192,263 | 292,910 | 152,840 | 154,951 | 157,608 | 159,921 | 162,387 | 164,930 | 167,589 | 169,898 | 172,223 | 174,986 | 177,305 | 179,754 | 182,335 | 184,661 | 186,910 | 189,206 | 191,702 | 194,168 |
| Operational Personnel | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445.00 | 910,445.00 | 910,445.00 | 910,445.00 | 910,445.00 | 910,445.00 | 910,445.00 |
| Electricity to plant | 36,929 | 38,365 | 39,857 | 41,408 | 43,018 | 44,691 | 46,429 | 48,235 | 50,111 | 52,060 | 54,085 | 56,189 | 58,374 | 60,644.33 | 63,003.01 | 65,453.43 | 67,999.15 | 70,643.88 | 73,391.48 | 76,245.94 |
| Steam | 24,306 | 25,251 | 26,233 | 27,254 | 28,314 | 29,415 | 30,559 | 31,747 | 32,982 | 34,265 | 35,598 | 36,982 | 38,421 | 39,914.99 | 41,467.43 | 43,080.25 | 44,755.79 | 46,496.51 | 48,304.93 | 50,183.68 |
| SCR Regeneration disposal | - | - | - | - | - | 60,593 | - | - | - | - | 52,571 | - | - | - | - | 56,515 | - | - | - | - |
| **Total Operations and Maintenance Costs** | 63,292,958 | 98,131,699 | 54,519,926 | 57,146,850 | 60,098,046 | 63,130,412 | 66,245,900 | 69,610,570 | 73,190,464 | 76,796,872 | 80,638,959 | 84,765,114 | 88,937,557 | 93,377,362 | 98,102,728 | 102,979,244 | 107,933,123 | 113,210,536 | 118,862,484 | 124,771,132 |
| **Total Costs** | 63,292,958 | 98,131,699 | 54,519,926 | 57,146,850 | 60,098,046 | 63,130,412 | 66,245,900 | 69,610,570 | 73,190,464 | 76,796,872 | 80,638,959 | 84,765,114 | 88,937,557 | 93,377,362 | 98,102,728 | 102,979,244 | 107,933,123 | 113,210,536 | 118,862,484 | 124,771,132 |
| NPV | £997,352,398 | | | | | | | | | | | | | | | | | | | |

## Gas Option (Existing and Extension)

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Infrastructural Cost (Pipeline Option) | - | - | 273,621,846 | | | | | | | | | | | | | | | | | |
| Conversion of existing plant | - | - | 35,000,000 | | | | | | | | | | | | | | | | | |
| Residual | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - 113,161,344 |
| **Capital Costs** | - | - | 308,621,846 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - 113,161,344 |
| **Operational and Maintenance** | | | | | | | | | | | | | | | | | | | | |
| Fuel Costs (HFO) | 0 | 0 | 0 | 31,272,304 | 33,047,283 | 34,838,088 | 36,752,950 | 38,782,348 | 40,942,367 | 43,122,585 | 45,414,717 | 47,940,567 | 50,467,283 | 53,156,486 | 56,019,304 | 58,942,831 | 61,983,589 | 65,187,764 | 68,619,244 | 72,208,317 |
| Lubricant oil cost | 0 | 0 | 0 | 790,558 | 835,429 | 880,700 | 929,107 | 980,410 | 1,035,015 | 1,090,130 | 1,148,075 | 1,211,928 | 1,275,803 | 1,343,785 | 1,416,157 | 1,490,063 | 1,566,933 | 1,647,934 | 1,734,681 | 1,825,412 |
| Urea Cost | 0 | 0 | 0 | 1,128,285 | 1,147,687 | 1,164,584 | 1,182,600 | 1,201,181 | 1,220,608 | 1,237,477 | 1,254,463 | 1,274,657 | 1,291,603 | 1,309,496 | 1,328,356 | 1,345,355 | 1,361,794 | 1,378,573 | 1,396,814 | 1,414,845 |
| Desox Reagent Cost | 0 | 0 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Maintenance Agreement | 0 | 0 | 0 | 3,123,718 | 3,150,287 | 3,174,320 | 3,198,903 | 3,224,485 | 3,251,163 | 3,274,134 | 3,297,400 | 3,324,995 | 3,348,354 | 3,372,884 | 3,398,636 | 3,421,910 | 3,444,849 | 3,467,783 | 3,492,858 | 3,517,734 |
| Maintenance personnel | 0 | 0 | 0 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 |
| Waste Disposal | 0 | 0 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Operational Personnel | 0 | 0 | 0 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 |
| Electricity to plant | 0 | 0 | 0 | 30,511 | 31,698 | 32,931 | 34,212 | 35,542 | 36,925 | 38,361 | 39,853 | 41,403 | 43,013 | 44,686 | 46,424 | 48,230 | 50,106 | 52,054 | 54,079 | 56,182 |
| Steam | 0 | 0 | 0 | 20,082 | 20,863 | 21,675 | 22,518 | 23,393 | 24,303 | 25,248 | 26,230 | 27,251 | 28,311 | 29,412 | 30,556 | 31,744 | 32,979 | 34,261 | 35,594 | 36,978 |
| SCR Regeneration disposal | 0 | 0 | 0 | - | - | 60,593 | - | - | - | - | 52,571 | - | - | - | - | 56,515 | - | - | - | - |
| **Total Operations and Maintenance Costs** | 43,354,190 | 66,417,886 | 37,246,428 | 37,864,694 | 39,732,484 | 41,672,127 | 43,619,527 | 45,746,597 | 48,009,618 | 50,287,173 | 52,732,547 | 55,320,037 | 57,953,603 | 60,755,986 | 63,738,670 | 66,835,884 | 69,939,486 | 73,267,607 | 76,832,507 | 80,558,705 |
| Net Savings in Operations and Maintenance Costs in runnning existing Delimara | - | - | - | 1,593,845 | 1,676,186 | 1,756,946 | 1,872,920 | 2,000,968 | 2,107,893 | 2,256,369 | 2,399,743 | 2,573,271 | 2,801,101 | 2,959,745 | 3,198,735 | 3,403,152 | 3,679,263 | 3,921,252 | 4,213,794 | 4,470,566 |
| **Total Costs** | 43,354,190 | 66,417,886 | 345,868,274 | 36,270,849 | 38,056,298 | 39,915,181 | 41,746,607 | 43,745,629 | 45,901,725 | 48,030,804 | 50,332,804 | 52,746,766 | 55,152,502 | 57,796,241 | 60,539,934 | 63,432,732 | 66,260,223 | 69,346,355 | 72,618,713 | - 37,073,205 |
| NPV | £856,011,612 | | | | | | | | | | | | | | | | | | | |

## Annex 3: Detailed Results of the Economic (Incorporating Financial and Emissions) Model

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Scenario I: Extension on HFO** | | | | | | | | | | | | | | | | | | | | |
| **Operational and Maintenance** | | | | | | | | | | | | | | | | | | | | |
| Fuel Costs (HFO) | 32,204,684 | 50,970,820 | 27,628,561 | 29,099,782 | 30,749,858 | 32,414,964 | 34,195,017 | 36,081,498 | 38,089,250 | 40,115,818 | 42,246,375 | 44,593,818 | 46,942,306 | 49,441,612 | 52,102,059 | 54,819,026 | 57,645,080 | 60,622,696 | 63,811,351 | 67,146,404 |
| Lubricant oil cost | 957,292 | 1,515,120 | 821,266 | 864,998 | 914,047 | 963,543 | 1,016,455 | 1,072,532 | 1,132,213 | 1,192,453 | 1,255,784 | 1,325,562 | 1,395,372 | 1,469,664 | 1,548,747 | 1,629,509 | 1,713,514 | 1,802,025 | 1,896,808 | 1,995,944 |
| Urea Cost | 1,366,320 | 2,081,535 | 1,086,049 | 1,101,057 | 1,119,933 | 1,136,379 | 1,153,904 | 1,171,980 | 1,190,877 | 1,207,283 | 1,223,804 | 1,243,443 | 1,259,925 | 1,277,326 | 1,295,666 | 1,312,195 | 1,328,184 | 1,344,498 | 1,362,234 | 1,379,766 |
| Desox Reagent Cost | 1,736,132 | 2,697,828 | 1,435,754 | 1,484,707 | 1,540,363 | 1,594,243 | 1,651,205 | 1,710,613 | 1,772,959 | 1,833,332 | 1,895,588 | 1,964,528 | 2,030,379 | 2,099,590 | 2,172,330 | 2,244,043 | 2,316,815 | 2,392,177 | 2,472,209 | 2,554,107 |
| Maintenance Agreement | 3,508,554 | 4,512,683 | 3,102,383 | 3,123,718 | 3,150,287 | 3,174,320 | 3,198,903 | 3,224,485 | 3,251,163 | 3,274,134 | 3,297,400 | 3,324,995 | 3,348,354 | 3,372,884 | 3,398,636 | 3,421,910 | 3,444,849 | 3,467,783 | 3,492,858 | 3,517,734 |
| Maintenance personnel | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 |
| Waste Disposal | 2,017,708 | 3,073,900 | 1,603,819 | 1,625,982 | 1,653,857 | 1,678,144 | 1,704,023 | 1,730,718 | 1,758,624 | 1,782,851 | 1,807,248 | 1,836,251 | 1,860,590 | 1,886,287 | 1,913,370 | 1,937,779 | 1,961,391 | 1,985,482 | 2,011,674 | 2,037,565 |
| Operational Personnel | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 |
| Electricity to plant | 38,755 | 40,262 | 41,828 | 43,455 | 45,145 | 46,901 | 48,725 | 50,620 | 52,589 | 54,635 | 56,760 | 58,967 | 61,261 | 63,643 | 66,119 | 68,690 | 71,362 | 74,137 | 77,021 | 80,016 |
| Steam | 25,508 | 26,500 | 27,531 | 28,601 | 29,714 | 30,869 | 32,070 | 33,317 | 34,613 | 35,960 | 37,358 | 38,811 | 40,321 | 41,889 | 43,518 | 45,211 | 46,969 | 48,796 | 50,694 | 52,665 |
| SCR Regeneration disposal | - | - | - | - | - | 63,586 | - | - | - | - | 55,166 | - | - | - | - | 59,305 | - | - | - | - |
| **Total Operations and Maintenance Costs** | 43,354,190 | 66,417,886 | 37,246,428 | 38,871,537 | 40,702,442 | 42,602,187 | 44,499,540 | 46,575,000 | 48,781,525 | 50,995,703 | 53,374,720 | 55,885,613 | 58,437,744 | 61,152,132 | 64,039,681 | 67,036,905 | 70,027,400 | 73,236,832 | 76,674,086 | 80,263,438 |
| Min operations and Maintenance Costs | | | | | | | | | | | | | | | | | | | | |
| **Total Financial Costs** | 43,354,190 | 66,417,886 | 37,246,428 | 38,871,537 | 40,702,442 | 42,602,187 | 44,499,540 | 46,575,000 | 48,781,525 | 50,995,703 | 53,374,720 | 55,885,613 | 58,437,744 | 61,152,132 | 64,039,681 | 67,036,905 | 70,027,400 | 73,236,832 | 76,674,086 | 80,263,438 |
| **Economic Costs** | | | | | | | | | | | | | | | | | | | | |
| CO2 emissions | 9,919,484 | 15,094,935 | 7,826,007 | 7,935,970 | 8,072,914 | 8,196,781 | 8,323,489 | 8,455,339 | 8,592,842 | 8,711,243 | 8,831,159 | 8,973,385 | 9,093,784 | 9,220,214 | 9,352,947 | 9,472,901 | 9,591,134 | 9,709,342 | 9,838,584 | 9,966,798 |
| NOx emissions | 4,651,480 | 7,078,371 | 3,669,799 | 3,721,364 | 3,785,580 | 3,843,664 | 3,903,080 | 3,964,908 | 4,029,387 | 4,084,908 | 4,141,139 | 4,207,832 | 4,264,290 | 4,323,576 | 4,385,817 | 4,442,067 | 4,497,509 | 4,552,940 | 4,613,544 | 4,673,667 |
| SO2 emissions | 6,441,327 | 9,802,063 | 5,081,904 | 5,153,310 | 5,242,236 | 5,322,671 | 5,404,950 | 5,490,568 | 5,579,857 | 5,656,742 | 5,734,611 | 5,826,967 | 5,905,149 | 5,987,249 | 6,073,440 | 6,151,334 | 6,228,109 | 6,304,869 | 6,388,794 | 6,472,051 |
| Dust emissions | 6,453,437 | 9,820,492 | 5,091,459 | 5,162,999 | 5,252,092 | 5,332,677 | 5,415,111 | 5,500,891 | 5,590,348 | 5,667,377 | 5,745,392 | 5,837,922 | 5,916,251 | 5,998,505 | 6,084,858 | 6,162,898 | 6,239,818 | 6,316,723 | 6,400,805 | 6,484,219 |
| **Nh3** | 232,552 | 354,283 | 184,849 | 187,403 | 190,616 | 193,415 | 196,398 | 199,474 | 202,691 | 205,483 | 208,295 | 211,638 | 214,443 | 217,405 | 220,526 | 223,339 | 226,061 | 228,837 | 231,856 | 234,840 |
| **Arsenic** | 278,575 | 423,920 | 219,783 | 222,871 | 226,717 | 230,195 | 233,754 | 237,456 | 241,318 | 244,643 | 248,011 | 252,005 | 255,386 | 258,937 | 262,665 | 266,033 | 269,354 | 272,673 | 276,303 | 279,904 |
| **Cardmium** | 2,036 | 3,098 | 1,606 | 1,629 | 1,657 | 1,682 | 1,708 | 1,735 | 1,764 | 1,788 | 1,813 | 1,842 | 1,866 | 1,892 | 1,920 | 1,944 | 1,969 | 1,993 | 2,019 | 2,046 |
| **Total Economic Costs** | **27978889.49** | **42577162.75** | **22075406.59** | **22385544.9** | **22771810.77** | **23121084.94** | **23478489.82** | **23850373.13** | **24238206.36** | **24572184.55** | **24910419.14** | **25311590.62** | **25651169.8** | **26007778.23** | **26382172.16** | **26720517.74** | **27053953.52** | **27387378.27** | **27751904.67** | **28113524.61** |
| **Total Costs** | **71,333,079** | **108,995,049** | **59,321,834** | **61,257,082** | **63,474,253** | **65,723,272** | **67,978,030** | **70,425,373** | **73,019,731** | **75,567,887** | **78,285,139** | **81,197,203** | **84,088,914** | **87,159,910** | **90,421,853** | **93,757,423** | **97,081,354** | **100,624,210** | **104,425,991** | **108,376,962** |
| NPV | 945,628,116 | | | | | | | | | | | | | | | | | | | |

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SCENARIO II: Extension on Gasoil** | | | | | | | | | | | | | | | | | | | | |
| Savings in abatement equipment | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Tank Containers | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Capital Costs** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Operational and Maintenance** | | | | | | | | | | | | | | | | | | | | |
| Fuel Costs (Gasoil) | 55,543,807 | 87,911,299 | 47,656,018 | 50,193,550 | 53,039,651 | 55,911,272 | 58,981,586 | 62,235,358 | 65,698,322 | 69,193,850 | 72,868,668 | 76,917,599 | 80,968,215 | 85,279,029 | 89,867,838 | 94,554,094 | 99,428,204 | 104,564,041 | 110,063,768 | 115,815,924 |
| Lubricant oil cost | 956,834 | 1,514,418 | 820,954 | 864,667 | 913,696 | 963,164 | 1,016,055 | 1,072,107 | 1,131,762 | 1,191,979 | 1,255,283 | 1,325,033 | 1,394,812 | 1,469,072 | 1,548,122 | 1,628,851 | 1,712,815 | 1,801,289 | 1,896,031 | 1,995,121 |
| Urea Cost | 1,365,595 | 2,080,462 | 1,085,580 | 1,100,578 | 1,119,444 | 1,135,874 | 1,153,390 | 1,171,456 | 1,190,342 | 1,206,741 | 1,223,253 | 1,242,882 | 1,259,354 | 1,276,746 | 1,295,076 | 1,311,597 | 1,327,573 | 1,343,879 | 1,361,605 | 1,379,126 |
| Desox Reagent Cost | 165,432 | 257,074 | 136,824 | 141,488 | 146,792 | 151,925 | 157,353 | 163,014 | 168,955 | 174,709 | 180,641 | 187,211 | 193,486 | 200,081 | 207,013 | 213,846 | 220,780 | 227,962 | 235,588 | 243,392 |
| Maintenance Agreement | 3,508,554 | 4,512,683 | 3,102,383 | 3,123,718 | 3,150,287 | 3,174,320 | 3,198,903 | 3,224,485 | 3,251,163 | 3,274,134 | 3,297,400 | 3,324,995 | 3,348,354 | 3,372,884 | 3,398,636 | 3,421,910 | 3,444,849 | 3,467,783 | 3,492,858 | 3,517,734 |
| Maintenance personnel | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 |
| Waste Disposal | 192,263 | 292,910 | 152,840 | 154,951 | 157,608 | 159,921 | 162,387 | 164,930 | 167,589 | 169,898 | 172,223 | 174,986 | 177,305 | 179,754 | 182,335 | 184,661 | 186,910 | 189,206 | 191,702 | 194,168 |
| Operational Personnel | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 |
| Electricity to plant | 36,929 | 38,365 | 39,857 | 41,408 | 43,018 | 44,691 | 46,429 | 48,235 | 50,111 | 52,060 | 54,085 | 56,189 | 58,374 | 60,644 | 63,003 | 65,453 | 67,999 | 70,644 | 73,391 | 76,246 |
| Steam | 24,306 | 25,251 | 26,233 | 27,254 | 28,314 | 29,415 | 30,559 | 31,747 | 32,982 | 34,265 | 35,598 | 36,982 | 38,421 | 39,915 | 41,467 | 43,080 | 44,756 | 46,497 | 48,305 | 50,184 |
| SCR Regeneration disposal | - | - | - | - | - | 60,593 | - | - | - | - | 52,571 | - | - | - | - | 56,515 | - | - | - | - |
| **Total Operations and Maintenance Costs** | 63,292,958 | 98,131,699 | 54,519,926 | 57,146,850 | 60,098,046 | 63,130,412 | 66,245,900 | 69,610,570 | 73,190,464 | 76,796,872 | 80,638,959 | 84,765,114 | 88,937,557 | 93,377,362 | 98,102,728 | 102,979,244 | 107,933,123 | 113,210,536 | 118,862,484 | 124,771,132 |
| **Total Financial Costs** | 63,292,958 | 98,131,699 | 54,519,926 | 57,146,850 | 60,098,046 | 63,130,412 | 66,245,900 | 69,610,570 | 73,190,464 | 76,796,872 | 80,638,959 | 84,765,114 | 88,937,557 | 93,377,362 | 98,102,728 | 102,979,244 | 107,933,123 | 113,210,536 | 118,862,484 | 124,771,132 |
| **Economic Costs** | | | | | | | | | | | | | | | | | | | | |
| CO2 emissions | 9,488,950 | 14,439,772 | 7,486,336 | 7,591,527 | 7,722,527 | 7,841,018 | 7,962,226 | 8,088,354 | 8,219,889 | 8,333,151 | 8,447,862 | 8,583,915 | 8,699,088 | 8,820,032 | 8,947,003 | 9,061,751 | 9,174,852 | 9,287,930 | 9,411,562 | 9,534,211 |
| NOx emissions | 6,441,327 | 9,802,063 | 5,081,904 | 5,153,310 | 5,242,236 | 5,322,671 | 5,404,950 | 5,490,568 | 5,579,857 | 5,656,742 | 5,734,611 | 5,826,967 | 5,905,149 | 5,987,249 | 6,073,440 | 6,151,334 | 6,228,109 | 6,304,869 | 6,388,794 | 6,472,051 |
| SO2 emissions | 2,325,740 | 3,539,186 | 1,834,900 | 1,860,682 | 1,892,790 | 1,921,832 | 1,951,540 | 1,982,454 | 2,014,693 | 2,042,454 | 2,070,569 | 2,103,916 | 2,132,145 | 2,161,788 | 2,192,909 | 2,221,034 | 2,248,755 | 2,276,470 | 2,306,772 | 2,336,833 |
| Dust emissions | 3,872,062 | 5,892,295 | 3,054,875 | 3,097,799 | 3,151,255 | 3,199,606 | 3,249,067 | 3,300,535 | 3,354,209 | 3,400,426 | 3,447,235 | 3,502,753 | 3,549,751 | 3,599,103 | 3,650,915 | 3,697,739 | 3,743,891 | 3,790,034 | 3,840,483 | 3,890,531 |
| **Nh3** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Arsenic** | | | | | | | | | | | | | | | | | | | | |
| **Cardmium** | | | | | | | | | | | | | | | | | | | | |
| **Total Economic Costs** | 22,128,079 | 33,673,317 | 17,458,016 | 17,703,318 | 18,008,808 | 18,285,126 | 18,567,783 | 18,861,911 | 19,168,648 | 19,432,773 | 19,700,278 | 20,017,551 | 20,286,133 | 20,568,171 | 20,864,266 | 21,131,858 | 21,395,607 | 21,659,303 | 21,947,610 | 22,233,627 |
| **Total Costs** | **85,421,037** | **131,805,016** | **71,977,941** | **74,850,168** | **78,106,854** | **81,415,538** | **84,813,683** | **88,472,481** | **92,359,112** | **96,229,646** | **100,339,237** | **104,782,665** | **109,223,690** | **113,945,533** | **118,966,994** | **124,111,101** | **129,328,730** | **134,869,840** | **140,810,095** | **147,004,759** |
| NPV | £1,199,118,887 | | | | | | | | | | | | | | | | | | | |

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SCENARIO III: Gas Option (Existing and Extension)** | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| Infrastructural Cost (Pipeline Option) | - | - | 273,621,846 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Conversion of existing plant | - | - | 35,000,000 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Residual | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - 113,161,344 |
| | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Capital Costs** | - | - | 308,621,846 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - 113,161,344 |
| **Operational and Maintenance** | | | | | | | | | | | | | | | | | | | | |
| Fuel Costs (HFO) | - | - | - | 31,272,304 | 33,047,283 | 34,838,088 | 36,752,950 | 38,782,348 | 40,942,367 | 43,122,585 | 45,414,717 | 47,940,567 | 50,467,283 | 53,156,486 | 56,019,304 | 58,942,831 | 61,983,589 | 65,187,764 | 68,619,244 | 72,208,317 |
| Lubricant oil cost | - | - | - | 790,558 | 835,429 | 880,700 | 929,107 | 980,410 | 1,035,015 | 1,090,130 | 1,148,075 | 1,211,928 | 1,275,803 | 1,343,785 | 1,416,157 | 1,490,063 | 1,566,933 | 1,647,934 | 1,734,681 | 1,825,412 |
| Urea Cost | - | - | - | 1,128,285 | 1,147,687 | 1,164,584 | 1,182,600 | 1,201,181 | 1,220,608 | 1,237,477 | 1,254,463 | 1,274,657 | 1,291,603 | 1,309,496 | 1,328,356 | 1,345,355 | 1,361,794 | 1,378,573 | 1,396,814 | 1,414,845 |
| Desox Reagent Cost | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Maintenance Agreement | - | - | - | 3,123,718 | 3,150,287 | 3,174,320 | 3,198,903 | 3,224,485 | 3,251,163 | 3,274,134 | 3,297,400 | 3,324,995 | 3,348,354 | 3,372,884 | 3,398,636 | 3,421,910 | 3,444,849 | 3,467,783 | 3,492,858 | 3,517,734 |
| Maintenance personnel | - | - | - | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 |
| Waste Disposal | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Operational Personnel | - | - | - | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 |
| Electricity to plant | - | - | - | 30,511 | 31,698 | 32,931 | 34,212 | 35,542 | 36,925 | 38,361 | 39,853 | 41,403 | 43,013 | 44,686 | 46,424 | 48,230 | 50,106 | 52,054 | 54,079 | 56,182 |
| Steam | - | - | - | 20,082 | 20,863 | 21,675 | 22,518 | 23,393 | 24,303 | 25,248 | 26,230 | 27,251 | 28,311 | 29,412 | 30,556 | 31,744 | 32,979 | 34,261 | 35,594 | 36,978 |
| SCR Regeneration disposal | - | - | - | - | - | 60,593 | - | - | - | - | 52,571 | - | - | - | - | 56,515 | - | - | - | - |
| **Total Operations and Maintenance Costs** | 43,354,190 | 66,417,886 | 37,246,428 | 37,864,694 | 39,732,484 | 41,672,127 | 43,619,527 | 45,746,597 | 48,009,618 | 50,287,173 | 52,732,547 | 55,320,037 | 57,953,603 | 60,755,986 | 63,738,670 | 66,835,884 | 69,939,486 | 73,267,607 | 76,832,507 | 80,558,705 |
| Savings in Operations and Maintenance Costs in runnning existing Delimara | - | - | - | 1,593,845 | 1,676,186 | 1,756,946 | 1,872,920 | 2,000,968 | 2,107,893 | 2,256,369 | 2,399,743 | 2,573,271 | 2,801,101 | 2,959,745 | 3,198,735 | 3,403,152 | 3,679,263 | 3,921,252 | 4,213,794 | 4,470,566 |
| **Total Financial Costs** | 43,354,190 | 66,417,886 | 345,868,274 | 36,270,849 | 38,056,298 | 39,915,181 | 41,746,607 | 43,745,629 | 45,901,725 | 48,030,804 | 50,332,804 | 52,746,766 | 55,152,502 | 57,796,241 | 60,539,934 | 63,432,732 | 66,260,223 | 69,346,355 | 72,618,713 | - 37,073,205 |
| Economic Costs | | | | | | | | | | | | | | | | | | | | |
| CO2 emissions | - | - | - | 5,717,756 | 5,816,422 | 5,905,667 | 5,996,958 | 6,091,954 | 6,191,023 | 6,276,330 | 6,362,727 | 6,465,199 | 6,551,945 | 6,643,036 | 6,738,668 | 6,825,094 | 6,910,279 | 6,995,446 | 7,088,563 | 7,180,940 |
| NOx emissions | - | - | - | 2,603,219 | 2,648,140 | 2,688,772 | 2,730,335 | 2,773,586 | 2,818,691 | 2,857,530 | 2,896,865 | 2,943,520 | 2,983,014 | 3,024,486 | 3,068,026 | 3,107,375 | 3,146,158 | 3,184,934 | 3,227,329 | 3,269,387 |
| SO2 emissions | - | - | - | | | | | | | | | | | | | | | | | |
| Dust emissions | - | - | - | 1,408,091 | 1,432,389 | 1,454,367 | 1,476,849 | 1,500,243 | 1,524,640 | 1,545,648 | 1,566,925 | 1,592,161 | 1,613,523 | 1,635,956 | 1,659,507 | 1,680,790 | 1,701,769 | 1,722,743 | 1,745,674 | 1,768,423 |
| Nh3 | | | | | | | | | | | | | | | | | | | | |
| Arsenic | | | | | | | | | | | | | | | | | | | | |
| Cardmium | | | | | | | | | | | | | | | | | | | | |
| **Total Economic Costs** | 27,978,889 | 42,577,163 | 22,075,407 | 9,729,065 | 9,896,951 | 10,048,805 | 10,204,142 | 10,365,784 | 10,534,355 | 10,679,508 | 10,826,518 | 11,000,879 | 11,148,481 | 11,303,479 | 11,466,201 | 11,613,259 | 11,758,206 | 11,903,123 | 12,061,566 | 12,218,750 |
| Net Savings in Economic Costs | | | | 219,735 | 235,971 | 250,231 | 272,785 | 296,499 | 312,668 | 337,411 | 358,657 | 384,718 | 420,280 | 438,122 | 470,428 | 493,061 | 527,065 | 551,905 | 583,194 | 605,608 |
| Net Economic Costs | 27,978,889 | 42,577,163 | 22,075,407 | 9,509,330 | 9,660,980 | 9,798,574 | 9,931,357 | 10,069,284 | 10,221,686 | 10,342,097 | 10,467,860 | 10,616,161 | 10,728,201 | 10,865,357 | 10,995,773 | 11,120,198 | 11,231,141 | 11,351,218 | 11,478,372 | 11,613,141 |
| **Total Costs** | **71,333,079** | **108,995,049** | **367,943,681** | **45,780,179** | **47,717,278** | **49,713,755** | **51,677,963** | **53,814,913** | **56,123,411** | **58,372,900** | **60,800,664** | **63,362,927** | **65,880,704** | **68,661,598** | **71,535,707** | **74,552,930** | **77,491,364** | **80,697,573** | **84,097,085** | **- 25,460,063** |
| NPV | £1,007,542,056 | | | | | | | | | | | | | | | | | | | |

**Annex 4: Risk Analysis** *(Source: SRL Risk Assessment Technical Report on the Delimara Power Station extension - October 2009)*

| | Hazards | Causes | Consequential level | Risk | Frequency |
|---|---|---|---|---|---|
| **1** | **Construction stage** | | | | |
| 1.1 | Loss of materials on site roadway | Driver error, collision or improper control causing spill from vehicle | L | Tolerable | Unexpected |
| 1.2 | Loss of containment in temporary construction area | Inadequate storage of harmful or hazardous substances | L | Tolerable | Unexpected |
| 1.3 | Loss of containment from existing facilities | Impact or damage to existing facilities | S | Tolerable | Remote |
| 1.4 | Loss of containment from existing facilities | Improper connection to existing plant resulting ion loss of control or containment | S | Tolerable | Very Unlikely |
| 1.5 | Unstable or inadequate construction techniques | Poor construction technique and control and contaminated land | L | Tolerable | Unexpected |

| | Hazards | Causes | Consequential level | Risk | Frequency |
|---|---|---|---|---|---|
| **2** | **Quay reception and delivery by pipeline of oil to storage and tank farm area (existing facilities already managed - not considered further)** | | | | |
| 2.1 | Existing activity regulated and controlled. Unchanged risk for new plant so exclude from QRA | Equipment failure or human error at low monitoring times. eg. at night | M | Tolerable | **Unlikely** |
| **3** | **Delivery of oil by new pipework from existing tank farm to new service tank farm area and to powerhouse** | | | | |
| 3.1 | Vehicle impact resulting in damage to new pipework and loss with potential for environmental effect | Driver error, collision or improper control causing spill from vehicle | L | Tolerable | **Unlikely** |
| 3.2 | Loss of containment ion transfer facilities | Inadequate design and specification resulting in leakage, overpressure etc. | L | Tolerable | **Unlikely** |
| 3.3 | Loss of containment ion transfer facilities | Poor operation of facilities resulting in spillage | L | Tolerable | Unexpected |

| | Hazards | Causes | Consequential level | Risk | Frequency |
|---|---|---|---|---|---|
| **4** | **Service tank farm area - new day storage tanks** | | | | |
| 4.1 | Loss of containment in tank farm | Poor operational control resulting in overfilling of tanks with spillage | L | Tolerable | **Unlikely** |
| 4.2 | Loss of containment in tank farm | Poor design and maintenance resulting in spillage | L | Tolerable | **Unlikely** |
| 4.3 | Containment and drainage systems | Spillage at time of low supervision (eg night) overwhelms drainage system | S | Tolerable | **Unlikely** |
| **5** | **Treatment chemicals Air Pollution Control (APC) - Urea and Bicarbonate plants** | | | | |
| 5.1 | Loss of Urea/DeSox containment | Poor delivery practices resulting in accidental spillage, mis-delivery, overfilling of tanks, etc. resulting in spillage or excess waste | L | Tolerable | **Unlikely** |
| 5.2 | Loss of Urea/DeSox containment | Poor operational control resulting in loss, spillage or overuse generating excess waste | L | Tolerable | Unexpected |
| 5.3 | Loss of containment or loss of control during use or maintenance | Poor design, maintenance and use of boiler treatment chemicals, inadequate treatment and control of wash effluents | S | Tolerable | Unexpected |
| 5.4 | Loss of containment | Poor design and maintenance resulting in loss with spillage generating waste | L | Tolerable | Unlikely |
| 5.5 | VOC vapour line ignition | Poor maintenance resulting in vapour breakthrough | M | Tolerable | Unlikely |

# Addendum

Following Meeting held at the Malta Environment and Planning Authority (MEPA) and formal submission on the initial review of the submitted report

**July 2011**

1. <u>Objective</u>

The scope of this addendum is to present an extension of the baseline model presented in the report above as well as revised workings. The revised model and results have been undertaken following the submission of comments by the Malta Environmental and Planning Authority as well as a meeting with the Authority and key stakeholders related to the IPPC permit. Towards this end, this addendum captures the following elements:

1. A revision of the baseline model to take into account the inclusion of:
    a. $CO_2$ emissions trading, the price of which is based on projections issued by the EU Commission[10]. A sensitivity assessment on this variable has also been carried out to highlight the financial implications of this variable.
    b. Cost of HFO and Gasoil fabric filters as submitted by Enemalta.
2. Presentation of an additional sensitivity scenario whereby the pecking order in the use of facilities to satisfy the demand for energy, commences with the Delimara extension followed by the Interconnector.
3. Presentation of a formula which captures the PDC, from a financial and externality viewpoint, of running the DPS extension on a mix of fuel between HFO and Gasoil for the period covered by the IPPC permit.

[10] Communication from the Commission: Guidance document on the optional application of Article 10c of Directive 2003/87/EC (2011/C 99/03)

## 2. Revised Baseline Model

### 2.1 Inclusion of $CO_2$ emissions trading in the financial model

Article 10c of Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishes a scheme for greenhouse gas emissions allowance trading within the Community and amends Council Directive 96/61/EC which allows Member States, whose electricity systems meet certain criteria, to provide for a transitional free allocation of emission allowances between 2013 and 2020 to installations for electricity production.

The Directive which establishes auctioning as the basic principle for the allocation of emission allowances also establishes criteria for the provision of a phasing out of the allowances whereby the criteria relate to the need to modernise the energy system. Member States which may decide to use this option must in parallel undertake action aimed at securing investments in the energy system such as upgrades of the infrastructure and clean technologies. The Directive also indicates that Member States meeting the criteria are however not required to use this option and may well choose not to.

For the purpose of estimating the financial implications of such emissions on the DPS extension, it is assumed that such a phasing out allocation of free emission allowances will not be undertaken and that Enemalta will thus bear the full financial impact of these allowances.

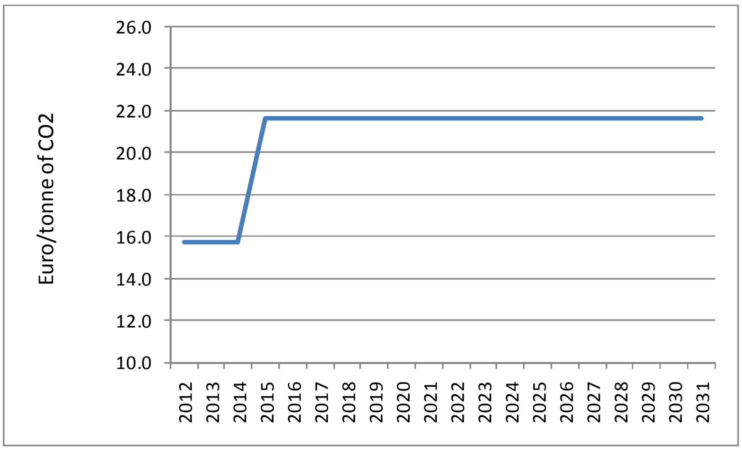
The price assumed for these allowances is based on a model based projection by the Commission for carbon prices in the third trading period. These prices stem from a baseline scenario defined in the Commission Staff Working Document accompanying the Communication titled '*Analysis of options to move beyond 20% greenhouse gas emission reductions and the risk of carbon leakage*.' Price projections based on 2005 and 2008 prices as presented by the Commission are reproduced in Table A1.

**Table A1: Carbon Price Projections**

| Carbon price projections annual average in Euro/tonne of $CO_2$ | 2010-2014 | 2015-2019 |
|---|---|---|
| Euro in (2005) | 13.6 | 18.7 |
| Euro in (2008) | 14.5 | 20 |
| Euro in (2012) - based on an average annual price inflation rate of 2% | 15.7 | 21.6 |

Price projections for the purpose of this assignment have thus been undertaken on the basis of the Commission forecasts adjusted for on an annual average price inflation of 2% which tallies with the forecast by the Commission between 2005 and 2008. This implies that the price per tonne of $CO_2$ at 2012 prices between 2010 and 2014 amounts to €15.7 and increases to €21.6 between 2015 to 2019. The real price of carbon emissions at 2012 prices is assumed constant thereafter as shown in Chart A1.

**Chart A1: Carbon Price Projections**




*2.1.1 Financial implication of emission allowances on DPS extension*

The net present cost of carbon emissions based on the Scenarios presented in the report is shown in Chart A2. The peak in the cost of emissions in 2013 is due to the higher load demand on the extension in that particular year which subsequently falls in 2014 as the interconnector is used at a higher capacity. In addition, the significant increase in 2015 is due to the higher project price of $CO_2$ emissions in that particular year which remain constant thereafter.

It is to be noted that in terms of the Gas option, the financial costs of $CO_2$ emissions as presented in the chart refer to $CO_2$ generated by Gas under the DPS extension. Due to the incremental approach adopted throughout the report, the net financial savings from emissions, which are based on the financial difference in the cost of emissions between running the existing DPS plant on Gas as opposed to running the existing DPS plant on HFO, are presented separately in Chart A3.

**Chart A2: Financial Implications of $CO_2$ Emissions**

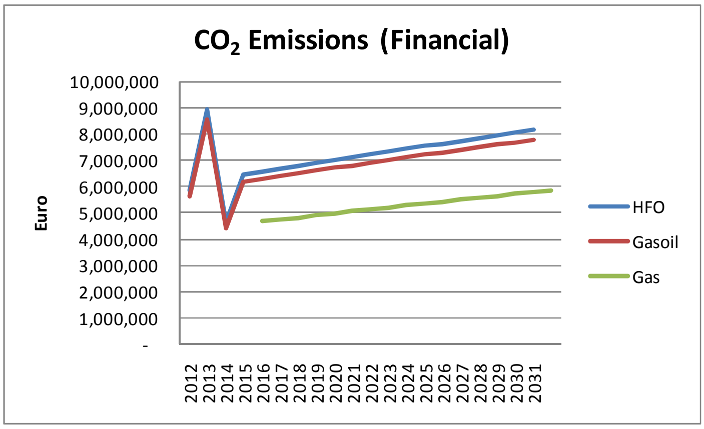
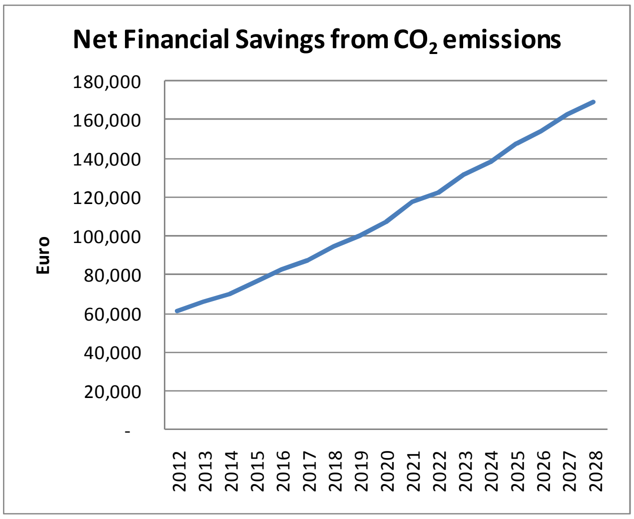


**Chart A3: Net Financial Savings from $CO_2$ Emissions from running Existing DPS on Gas**




<u>2.2 Cost of HFO and Gasoil fabric filters as submitted by Enemalta.</u>

The cost of fabric filters, as submitted by Enemalta, are to be incurred every second year estimated at Euro 400,000. Such cost is applicable only if the DPS extension is powered by HFO or Gasoil and not Gas.

3. <u>Estimation of Financial Costs</u>

<u>3.1 Revised Financial Results</u>

On the basis of the approach and methodology discussed in the report as well as the two modifications explained above, the financial model for the three scenarios over a 20-year horizon running to 2031 has been rerun and results are presented in Table A2. The results are here synthesized in terms of net present values using a time discount rate of 5%. Detailed results of the financial model for the three scenarios are presented in Annex A1.

**Table A2: Summary Results of the Financial Model**

| Net Present Value of Costs (€) | |
|---|---|
| | Baseline |
| Scenario I (HFO+Gasoil) | 752,875,214 |
| Scenario II (Gasoil) | 1,083,851,490 |
| Scenario III (Gas) | 923,468,193 |
| | |
| Proportion of GDP | |
| Scenario I (HFO+Gasoil) | 0.6% |
| Scenario II (Gasoil) | 0.9% |
| Scenario III (Gas) | 0.8% |
| GDP (NPV) | 122,190,125,467 |

As can be seen from the Table, the net financial present value under Scenario I, which models the use of the financially more favourable fuel between HFO and Gasoil, which is thus effectively HFO, amounts to €752.9 million. The Gasoil scenario at €1,083.9 million is over 40% more expensive than HFO. The net financial present value of the Gas scenario is €923.5 million which is also more financially expensive compared to HFO. This is essentially due to the high investment costs associated with the Gas option. This is evident from Table A3 wherein capital costs associated with gas constitute 24.3% of the total financial costs in net present value terms. The investment cost is net of its residual value, whereby the residual value is taken as the value of the remaining life of the investment infrastructure, estimated to amount to 10 years out of a total of 30 years.

It is also to be noted that in terms of the operations and maintenance costs, the fuel costs of each of the three scenarios constitutes the highest financial component ranging from 56.7% in the case of Gas to 83% in the terms of running the DPS extension on Gasoil. The proportion of emission allowances to total operations and maintenance costs range from 11.7% in Scenario I that is effectively running the extension on HFO, to 7.8% under the HFO scenario to an even lower proportion of 6.3% under the Gas option as can be seen from Table A4. In terms of the latter cost, the proportion displayed in the table refers to the costs of emission allowances associated with the extension prior to the deduction of net savings from running the existing plant on Gas.

Once again, the net present value figures for costs are scaled to a Gross Domestic Product (GDP) parameter, to capture the implications of differences in financial costs between the scenarios in terms of the burden relative to the output of the economy. Assuming an average real GDP growth of 2.5% during the forecast horizon, the cost of using HFO to fuel the DPS extension would amount to 0.6% of GDP, that of using Gasoil would be 0.9% of GDP, and that of using Gas would absorb 0.8% of GDP.

**Table A3: Financial Cost elements in NPV terms as a proportion of total costs**

| Proportion of NPV | HFO | Gasoil | Gas* |
|---|---|---|---|
| **Capital Costs** | | | 24.3% |
| **Operational and Maintenance** | | | |
| Fuel Costs | 69.3% | 83.0% | 56.7% |
| Lubricant oil cost | 2.1% | 1.4% | 1.4% |
| Urea Cost | 2.1% | 1.5% | 1.5% |
| Desox Reagent Cost | 3.2% | 0.2% | 0.0% |
| Maintenance Agreement | 5.6% | 3.9% | 4.0% |
| Maintenance personnel | 1.0% | 0.7% | 0.7% |
| Waste Disposal | 3.1% | 0.2% | 0.0% |
| Operational Personnel | 1.5% | 1.0% | 1.1% |
| Electricity to plant | 0.1% | 0.1% | 0.0% |
| Steam | 0.1% | 0.0% | 0.0% |
| SCR Regeneration disposal | 0.0% | 0.0% | 0.0% |
| Fabric Filters | 0.3% | 0.2% | - |
| $CO_2$ Emission Allowances | 11.7% | 7.8% | 6.3% |
| Operations and Maintenance prior to set off Gas operations | 100.0% | 92.0% | 78.6% |
| Savings in Operations and Maintenance Costs in runnning existing Delimara | | | 2.8% |
| Proportion of NPV | 100.0% | 100.0% | 100.0% |

*Gas option refers to existing and extension running on Gas with savings in costs on operations and maintenance of existing plant taken as a separate variable

**Table A4: Cost Components of the Scenarios**

| | HFO | Gasoil | Gas |
|---|---|---|---|
| NPV | | | |
| **Infrastructural Costs** | **-** | **-** | **223,949,834** |
| *Operations and Maintenance Costs* | | | |
| Fuel Costs | 521,368,130 | 899,272,477 | 523,431,995 |
| Lubricant oil cost | 15,497,799 | 15,491,457 | 13,232,255 |
| Urea Cost | 16,023,729 | 16,016,307 | 14,116,474 |
| Desox Reagent Cost | 23,916,568 | 2,279,117 | 0 |
| Maintenance Agreement | 42,196,154 | 42,196,154 | 37,138,442 |
| Maintenance personnel | 7,337,650 | 7,337,650 | 6,638,080 |
| Waste Disposal | 23,662,988 | 2,254,949 | 0 |
| Operational Personnel | 11,346,157 | 11,346,157 | 10,264,417 |
| Electricity to plant | 668,516 | 637,015 | 454,324 |
| Steam | 440,005 | 419,272 | 299,028 |
| SCR Regeneration disposal | 106,871 | 101,843 | 119,394 |
| Fabric Filters | 2,492,442 | 2,492,442 | |
| $CO_2$ Emission Allowances | 87,818,204 | 84,006,650 | 58,478,261 |
| Operations and Maintenance prior to set off Gas operations | 752,875,214 | 1,083,851,490 | 725,520,280 |
| Savings in Operations and Maintenance Costs in runnning existing Delimara | | | 26,001,921 |
| **Total Operations and Maintenace** | **752,875,214** | **1,083,851,490** | **699,518,359** |
| Total Costs | 752,875,214 | 1,083,851,490 | 923,468,193 |

## 3.2 Prime Dynamic Financial Cost (PDC)

The PDC is the total cost, investment and operational, of each of the fuel options in relation to the amount of electricity generated during the 20-year horizon of analysis. The objective of presenting the prime dynamic cost is to assess the implications of the decision on the average cost of producing electricity per MwH. As indicated in the main report, given the cost recovery formula currently being adopted by the Malta Resources Authority in the determination of tariff rates, this indicator would have a bearing on tariff levels in the economy. Towards this end, the following methodology has been adopted.

C(Q) is defined as the total cost of producing all (Q) MwH of electricity.

Therefore the change in overall average cost of the total MwH produced is

$$\frac{\delta(C(Q)/Q)}{\delta Q}$$

which may be expressed in two ways:

$$\frac{Q\,\delta C - C\,\delta Q}{Q^2} = \frac{\delta C}{Q} - \frac{C}{Q}\frac{\delta Q}{Q} \qquad \text{(a)}$$

or

$$\frac{Q\,(\delta C/\,\delta Q) - C}{Q^2} = \frac{(\delta C/\delta Q)}{Q} - \frac{C}{Q} \qquad \text{(b)}$$

Either way, the term which is of interest for the purpose of this assignment in determining the prime dynamic cost is the one highlighted in grey, because it shows the effect of the incremental decision being taken on the way to fuel the extension.

Under (a), the highlighted term expresses the incremental change in cost across all units produced, whether incremental or existing. This would indicate the change in costs spread over all the units produced. Under (b), the highlighted term expresses the incremental change in cost expressed per incremental unit produced.

In order to obtain comparable values, the prime dynamic cost for each of the three fuels is being expressed as follows:

a. PDC derived on the basis of Incremental costs divided by total units produced
b. PDC derived on the basis of Incremental costs divided by incremental units produced (i.e. the output of the extension)

Values obtained under (a) are thus comparable, and likewise those obtained under (b) are comparable. However values obtained under (a) are not comparable with those obtained under (b).

Consequently the prime dynamic financial cost of each of the scenarios based on the methodology presented above is displayed in Table A5.

**Table A5: Prime Dynamic Financial Cost**

| | Financial | |
|---|---|---|
| | (a) PDC: Incremental Costs/Total Units (Existing and Extension) | (b) PDC: Incremental Costs/Incremental Units |
| HFO | 82.94 | 99.31 |
| Gasoil | 119.40 | 142.97 |
| Gas | 101.73 | 121.81 |
| | % Change from HFO | |
| Gasoil | 44.0% | 44.0% |
| Gas | 22.7% | 22.7% |

As can be seen from the Table the PDC of running the DPS extension on HFO when taking into consideration the total untis produced by both the existing plant and the extension, is €82.94/Mwh while the PDC of running the extension on Gasoil is 44% higher than HFO. Similiarly, the PDC of running the plant on Gas at €101.73/MwH is is 22.7% higher than HFO from a purely financial perspective. The prime dynamic cost based on an incremental approach presents an identical perchange change difference between Gasoil and HFO and simliarly between Gas and HFO.

## 4. Estimation of Externality and Economic Costs

### 4.1 Revised Aggregate Economic Costs

The economic impact of the DPS extension takes into account externalities which are effects on the welfare of society and the economy in general arising out of an economic activity for which no direct financial prices are paid. In the financial analysis presented above, the financial costs of $CO_2$ emissions have been taken into account by considering the price of $CO_2$ emissions as established by the market. This price is considered in the financial analysis as it would in effect constitute a financial impact on the entity.

However it is to be noted that this market price does not consider the wider economic impact of $CO_2$ emissions which includes an effect on human health, ecosystems and crops and building. The Handbook of Shadow Prices establishes the shadow price of $CO_2$ emissions, which includes these effects, at €0.0265/tonne. This shadow price effectively incorporates the financial market price of the emission as well as the wider economic impact of the emission. As a result, for the purpose of the economic analysis it is the shadow price which is used to determine the costs of the externalities.

A summary of the revised main economic results based on a discount rate of 5.5% over a 20 year period is presented in Table A.6. Annex A2 presents the full details of all the cost components inherent in the aggregate economic cost analysis.

**Table A6: Aggregate Economic Costs**[11]

| Net Present Value of Costs (€) | | | |
|---|---|---|---|
| | **Total Costs** | **Economic Costs** | **Financial Costs** |
| Scenario I (HFO+Gasoil) | 948,012,377 | 313,254,934 | 634,757,444 |
| Scenario II (Gasoil) | 1,201,503,148 | 247,738,127 | 953,765,021 |
| Scenario III (Gas) | 1,007,910,421 | 180,007,321 | 827,903,100 |

As can be seen from the Table, the economic conclusion presented in the main report remains valid. Scenarios I and III present, on aggregate, quite similar levels of costs, with Scenario I involving the use of HFO, showing some advantages over the other on account of its financial performance. Gas has the lowest costs from an emissions perspective, but this is not sufficient to outweigh its financial disadvantage compared to HFO in terms of aggregate cost performance. Thus, on the basis of this analysis, the aggregate cost of the Gas scenario, at just over €1bn in terms of net present value, is found

[11] Financial Costs presented in Table A2 do not tally with costs presented in Table A5 due to the different discounting rate used in the financial and economic assessment.

to be 6.3% more expensive than the scenario involving the use of HFO.  Gasoil, on the other hand, has a poor financial performance and an intermediate emissions performance, and emerges on aggregate to be almost 27% more expensive than the lowest cost scenario.

The prime dynamic cost from an economic perspective, which incorporates the financial costs as well as the externality, is presented in Table A7 whereby the economic prime dynamic cost of HFO based on total units amounts to €104.43/MwH compared to €111.03/MwH under the gas scenario. The prime dynamic cost based on incremental units amounts to €125.05/MwH under HFO compared to a unit cost of €132.95 under the gas scenario and €158.49/MwH under the Gasoil scenario.

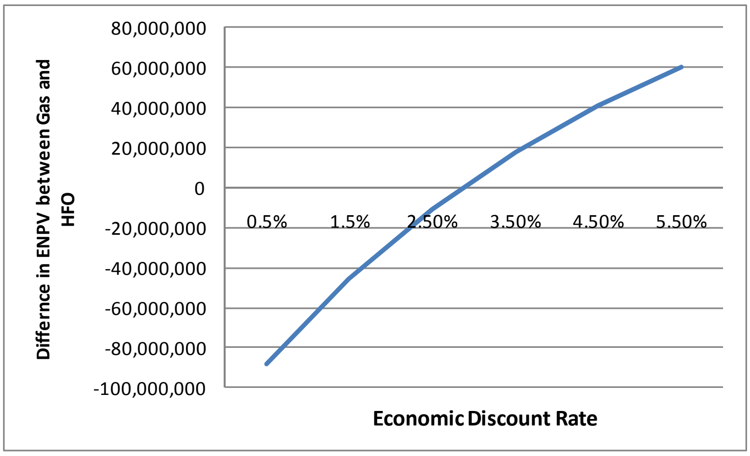
**Table A7: Economic Prime Dynamic Cost**

| Economic | | |
|---|---|---|
| | (a) PDC: Incremental Costs/Total Units (Existing and Extension) | (b) PDC: Incremental Costs/Incremental Units |
| HFO | 104.43 | 125.05 |
| Gasoil | 132.36 | 158.49 |
| Gas | 111.03 | 132.95 |
| % Change from HFO | | |
| Gasoil | 26.7% | 26.7% |
| Gas | 6.3% | 6.3% |

4.2 Economic Discount Rate

The discount rate is the rate at which future values are discounted to the present value. A lower discount rate implies that future values are discounted by a lower value thus rendering a lower valuation to the present value. This implies that for the purpose of this assignment, a lower discount rate would erode the marginal net economic present value of HFO compared to Gas as the difference in emissions over time between the two fuel options would outweigh the initial higher investment cost associated with Gas. Indeed as can be seen from Chart A4 below, the difference in the economic net present value between HFO and Gas would be completely eroded with an economic discount rate of about 3% in real terms.

**Chart A4: Economic Discount Rate**



## 5. Sensitivity Analyses

This section of the addendum presents the revised results of the eight different scenarios presented in the main report including;

- demand increases by 1% rather than 0.5% per annum
- demand for electricity remaining flat for the period of analysis;
- the price of crude oil rising by 10% per annum in real terms rather than the 4% assumed in the baseline model;
- the relativity between the price of Gasoil and that of HFO widening by 50%;
- the relativity between the price of Gas and that of HFO widening by 50%;
- the investment cost in the Gas infrastructure rising by 10%;
- the shadow prices of emissions rising by 10%;
- a higher load of electricity demand being satisfied through interconnection facilities from 2020 onwards.

In addition two additional scenarios have been developed. These include:

- a higher load of electricity demand being first and foremost met by the DPS extension as opposed to the interconnector.
- the market price of $CO_2$ emission allowances

### 5.1 Revised Sensitivity Analysis

Once again, the results of these sensitivity assessments are reported in terms of their effects on the net present values of the financial and economic costs under the three scenarios for different fuel use. Where relevant, switching values associated with the sensitivity assessments are also identified. These are the values of the parameters that are being changed in a sensitivity assessment at which the relative preference ranking of the different scenarios would change.

*Demand increases by 1% rather than 0.5% per annum*

Table A7 details the revised results of the scenario, taking into account the addition of the $CO_2$ emission allowances in the financial model as well as the fabric filters. The scenario is based on a situation where demand for electricity supplied by Enemalta increases by 1% rather than by 0.5% per annum. Such a situation could occur either because of a genuine increase in demand, reduced energy efficiency or because the economy makes less use of alternative sources of energy.

As can be expected, all scenarios for fuel use would feature higher financial and aggregate economic costs compared to the baseline. Costs rise more for the HFO and Gasoil scenarios due to the higher fuel component and higher element of emission allowances than for the Gas scenario. Once again from an economic perspective the HFO and Gas scenarios are almost equivalent so that an increase in demand of 1% per annum would constitute a switching value whereby the use of Gas would be equally preferred, from an aggregate economic viewpoint, to that of HFO. From a financial cost perspective, however, the HFO scenario remains preferable.

**Table A7: Sensitivity to Higher Growth in Electricity Demand**

| | Baseline: Demand increasing by 0.5% per annum | | Scenario: Demand increase by 1% | | Percentage Change | |
|---|---|---|---|---|---|---|
| | Financial | Economic | Financial | Economic | Financial | Economic |
| Scenario I (HFO+Gasoil) | 752,875,214 | 948,012,377 | 839,191,602 | 1,066,643,148 | 11.46% | 12.51% |
| Scenario II (Gasoil) | 1,083,851,490 | 1,201,503,148 | 1,217,878,014 | 1,356,967,305 | 12.37% | 12.94% |
| Scenario III (Gas) | 923,468,193 | 1,007,910,421 | 988,339,272 | 1,080,683,036 | 7.02% | 7.22% |

| Financial | | | | Economic | | |
|---|---|---|---|---|---|---|
| | (a) PDC: Incremental Costs/Total Units (Existing and Extension) | (b) PDC: Incremental Costs/Incremental Units | | (a) PDC: Incremental Costs/Total Units (Existing and Extension) | (b) PDC: Incremental Costs/Incremental Units |
| HFO | 72.16 | 87.99 | HFO | 102.55 | 125.05 |
| Gasoil | 109.02 | 132.93 | Gasoil | 130.53 | 159.16 |
| Gas | 88.74 | 108.20 | Gas | 104.10 | 126.93 |
| % Change from HFO | | | % Change from HFO | | |
| Gasoil | 51.1% | 51.1% | Gasoil | 27.3% | 27.3% |
| Gas | 23.0% | 23.0% | Gas | 1.5% | 1.5% |

*Demand for electricity remaining flat for the period of analysis*

A situation of zero demand growth for electricity supplied by Enemalta would result in lower costs through the use of HFO but to a lower extent in the use of Gas, as shown in Table A8. Once again this would produce a wider differential in terms of the financial and economic prime dynamic cost, between the use of HFO and Gas. As a result, the use of HFO would become increasingly preferable in a situation where there is a lower demand for energy supplied by Enemalta.

**Table A8: Sensitivity to No Growth in Electricity Demand**

| | Baseline: Demand increasing by 0.5% per annum | | Scenario: Flat Demand | | Percentage Change | |
|---|---|---|---|---|---|---|
| | Financial | Economic | Financial | Economic | Financial | Economic |
| Scenario I (HFO+Gasoil) | 752,875,214 | 948,012,377 | 664,560,529 | 826,119,645 | -11.73% | -12.86% |
| Scenario II (Gasoil) | 1,083,851,490 | 1,201,503,148 | 946,769,726 | 1,042,032,842 | -12.65% | -13.27% |
| Scenario III (Gas) | 923,468,193 | 1,007,910,421 | 844,119,975 | 917,595,824 | -8.59% | -8.96% |

| Financial | | | | Economic | | |
|---|---|---|---|---|---|---|
| | (a) PDC: Incremental Costs/Total Units (Existing and Extension) | (b) PDC: Incremental Costs/Incremental Units | | (a) PDC: Incremental Costs/Total Units (Existing and Extension) | (b) PDC: Incremental Costs/Incremental Units |
| HFO | 72.11 | 86.75 | HFO | 103.44 | 124.44 |
| Gasoil | 108.02 | 129.96 | Gasoil | 130.55 | 157.06 |
| Gas | 97.53 | 117.33 | Gas | 115.18 | 138.56 |
| % Change from HFO | | | % Change from HFO | | |
| Gasoil | 49.8% | 49.8% | Gasoil | 26.2% | 26.2% |
| Gas | 35.2% | 35.2% | Gas | 11.3% | 11.3% |

*The price of crude oil rising by 10% per annum in real terms rather than the 4% assumed in the baseline model*

Table A9 presents the revised results of a sensitivity assessment with respect to higher crude oil prices. Once again, the costs of all scenarios would increase, but under the Gas scenario, such increase would take place at a slower rate due to its lower fuel cost element within its total cost profile. It is however found that there needs to be an increase in the price of oil of over 40%, as compared to its expected baseline development, to create an equivalent financial cost between the use of HFO and Gas. Previously the switching value between HFO and Gas was higher at 60%. The reason for the decline in the switching value is due to the fact that the inclusion of the emission allowances and the fabric filters has narrowed the percentage difference between HFO and Gas such that the switching value has declined accordingly. Similarly the switching value from an economic perspective has declined to 0.59 implying that the price of crude oil would have to increase by 59% for the HFO to lose its economic advantage compared to Gas.

**TableA9: Sensitivity to Higher Crude Oil Prices**

| | Baseline: Price of Crude Oil increasing by 4% | | Scenario: Price of Crude Oil increasing by 10% | | Percentage Change | |
|---|---|---|---|---|---|---|
| | Financial | Economic | Financial | Economic | Financial | Economic |
| Scenario I (HFO+Gasoil) | 752,875,214 | 948,012,377 | 1,174,575,184 | 1,341,434,019 | 56.01% | 41.50% |
| Scenario II (Gasoil) | 1,083,851,490 | 1,201,503,148 | 1,801,738,466 | 1,871,249,525 | 66.23% | 55.74% |
| Scenario III (Gas) | 923,468,193 | 1,007,910,421 | 1,352,764,130 | 1,408,448,179 | 46.49% | 39.74% |
| | Financial | | | Economic | | |
| Baseline value | Price of Crude Oil increases by 4% per annum | | | | | |
| Switching value | Relative Price of 1.43 | | | Relative price of 1.59 | | |
| Notes: | Gas has a high fixed cost element. A substantial increase in the price of crude oil is needed to make it financially preferable. Also, a 59% increase per annum in the price of crude oil would erode the economic advantages of the gas option. To be noted that when the price of crude oil increases, the price of gas also increases. | | | | | |

*Relative price between Gasoil and HFO widening by 50%*

Table A10 shows the revised results of a sensitivity assessment whereby the differential between the price of Gasoil and that of HFO is increased by 50%. The introduction of $CO_2$ emission allowances and the fabric bag filters results in a drop in the switching value from that presented in the main report. Notwithstanding, the relative price of Gasoil to HFO would have to increase substantially for the financial and economic feasibility of the Gas option to match that of HFO.

**Table A10: Sensitivity to Increase in Gasoil Price Relative to HFO**

| | Baseline: Relative Price of Gasoil to HFO: 1.81 | | Scenario: Relative Price of Gasoil to HFO increases by 50% to 2.7 | | Percentage Change | |
|---|---|---|---|---|---|---|
| | Financial | Economic | Financial | Economic | Financial | Economic |
| Scenario I (HFO+Gasoil) | 752,875,214 | 948,012,377 | 752,875,214 | 948,012,377 | 0.00% | 0.00% |
| Scenario II (Gasoil) | 1,083,851,490 | 1,201,503,148 | 1,526,035,195 | 1,623,099,309 | 40.80% | 35.09% |
| Scenario III (Gas) | 923,468,193 | 1,007,910,421 | 901,438,933 | 987,219,810 | -2.39% | -2.05% |
| | Financial | | | Economic | | |
| Baseline value | Relative Price of Gasoil to HFO increases by 50% to 2.7 | | | | | |
| Switching value | Relative Price of 8.5 | | | Relative price of 4.4 | | |
| Notes: | Relative price of Gasoil to HFO would have to increase substantially for the financial feasibiltiy of Gas to match that of HFO. This is due to the fact that elements of Gas operations are fixed to Gasoil. In terms of the economic feasibility, the relative price of Gasoil to HFO woud need to increase more than four times , for HFO to lose its economic advantageous position. | | | | | |

*Relative price between Gas and HFO widening by 50%*

Table A11 presents the revised results of the sensitivity for an increase in the price of Gas relative to HFO by 50 percentage points, with the differential between the price of Gas and that of HFO thereby rising from 10% to 65%. Once again, the introduction of the CO2 emission allowances and the cost of the bag filters has narrowed the difference in the financial and economic net present value between HFO and Gas to the extent that the switching value has declined accordingly. As a result, given the revised costs, the price of gas would have to decline by 42% for the financial feasibility of HFO to be eroded and by 8% for the economic advantageous position of HFO to be eroded by the Gas scenario.

**Table A11: Sensitivity to Increase in Gasoil Price Relative to HFO**

| | Baseline: Relative Price of Gas to HFO: 1.1 | | Scenario: Relative Price of Gas to HFO increases by 50% to 1.65 | | Percentage Change | |
|---|---|---|---|---|---|---|
| | Financial | Economic | Financial | Economic | Financial | Economic |
| Scenario I (HFO+Gasoil) | 752,875,214 | 948,012,377 | 752,875,214 | 948,012,377 | 0.00% | 0.00% |
| Scenario II (Gasoil) | 1,083,851,490 | 1,201,503,148 | 1,083,851,490 | 1,201,503,148 | 0.00% | 0.00% |
| Scenario III (Gas) | 923,468,193 | 1,007,910,421 | 1,163,810,165 | 1,234,831,532 | 26.03% | 22.51% |
| | Financial | | | Economic | | |
| Baseline value | Relative Price of Gas to HFO increases by 50% to 1.65 | | | | | |
| Switching value | Relative price of 0.58 | | | Relative price of 0.92 | | |
| Notes: | Price of gas would have to be 42% lower than HFO for the gas option to be as financialy feasible as HFO. Also, price of gas would have to be 8% lower than HFO for the option to be as economically advantageous as HFO. | | | | | |

*Investment cost in the Gas infrastructure rising by 10%;*

The revised sensitivity analysis in terms of a 10% increase in gas infrastructure is presented in Table A12. As can be seen from the Table a 10% increase in such investment costs would deteriorate the net present value of the cost of using the Gas fuel by 2.4% from a financial perspective, and by 2.2% from an economic perspective. In terms of the switching value, investment costs of Gas would have to drop by 76% for Gas to be equivalent from a financial cost perspective to HFO. Also investment costs would have to be 25% lower than those set in the baseline for Gas to be on a par preference with HFO from an economic perspective.

**Table A12: Sensitivity to Increase in Gas Investment Costs**

| | Baseline: Investment Cost | | Scenario: A 10% increase in the investment cost of Gas | | Percentage Change | |
|---|---|---|---|---|---|---|
| | Financial | Economic | Financial | Economic | Financial | Economic |
| Scenario I (HFO+Gasoil) | 752,875,214 | 948,012,377 | 752,875,214 | 948,012,377 | 0.00% | 0.00% |
| Scenario I (HFO+Gasoil) | 1,083,851,490 | 1,201,503,148 | 1,083,851,490 | 1,201,503,148 | 0.00% | 0.00% |
| Scenario I (HFO+Gasoil) | 923,468,193 | 1,007,781,479 | 945,863,177 | 1,030,185,770 | 2.43% | 2.22% |
| | Financial | | | Economic | | |
| Baseline value | Investment Cost of Euro 297.621 million | | | | | |
| Switching value | Investment Cost lower by 76% | | | Investment cost lower by 25% | | |

*The shadow prices of emissions rising by 10%;*

Table A13 presents the revised implications of a 10% increase in the shadow prices of all emissions. The revised impact is marginal to the extent that the price of emissions would once again have to increase by about 41% for the Gas option to be equally preferred to the HFO option from an aggregate economic perspective.

**Table A13: Sensitivity to Higher Shadow Prices of Emissions**

| | Baseline: Price of emissions | | Scenario: A 10% increase in the price of Emissions | | Percentage Change | |
|---|---|---|---|---|---|---|
| | Financial | Economic | Financial | Economic | Financial | Economic |
| Scenario I (HFO+Gasoil) | 752,875,214 | 948,012,377 | 752,875,214 | 979,337,870 | 0.00% | 3.30% |
| Scenario II (Gasoil) | 1,083,851,490 | 1,201,503,148 | 1,083,851,490 | 1,226,276,961 | 0.00% | 2.06% |
| Scenario III (Gas) | 923,468,193 | 1,007,781,479 | 923,468,193 | 1,025,782,211 | 0.00% | 1.79% |
| | Financial | | | Economic | | |
| Baseline value | Baseline Price of Emissions | | | | | |
| Switching value | NA | | | Price of emissions increases by 41% | | |

*A higher load of electricity demand being satisfied through interconnection facilities from 2020 onwards*

The final revised sensitivity pertains to a higher load of electricity demand satisfied through interconnection facilities from 2020 onwards as shown in Chart A5. This may be occasioned by economic and financial considerations, as well as by regulatory issues concerning emissions and technology use in future. This scenario of reduced demand for local energy generation would put the Gas option at a disadvantage in view of its relatively high investment costs, with the other options being more favourable in the light of reduced fuel use and consequent greater reduction in emissions which would take place in such a situation. In fact, as can be seen from Table A14, the prime dynamic financial and economic cost of HFO and Gasoil based on incremental units decreases while the prime financial and economic dynamic cost of the gas option increases when compared to the baseline situation.

**Chart A5: Sensitivity to Use of Interconnector Facility**

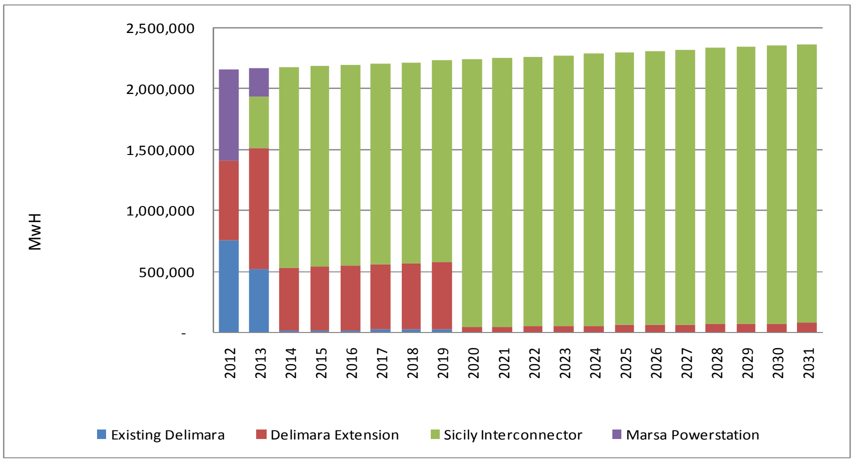



**Table A14: Sensitivity to Higher Load on Interconnector from 2020 onwards**

| Baseline | | | | | |
|---|---|---|---|---|---|
| Financial | | | Economic | | |
| | (a) PDC: Incremental Costs/Total Units (Existing and Extension) | (b) PDC: Incremental Costs/Incremental Units | | (a) PDC: Incremental Costs/Total Units (Existing and Extension) | (b) PDC: Incremental Costs/Incremental Units |
| HFO | 82.94 | 99.31 | HFO | 104.43 | 125.05 |
| Gasoil | 119.40 | 142.97 | Gasoil | 132.36 | 158.49 |
| Gas | 101.73 | 121.81 | Gas | 111.03 | 132.95 |
| **Higher load on interconnector from 2020** | | | | | |
| Financial | | | Economic | | |
| | (a) PDC: Incremental Costs/Total Units (Existing and Extension) | (b) PDC: Incremental Costs/Incremental Units | | (a) PDC: Incremental Costs/Total Units (Existing and Extension) | (b) PDC: Incremental Costs/Incremental Units |
| HFO | 70.95 | 92.06 | HFO | 93.30 | 121.06 |
| Gasoil | 99.06 | 128.53 | Gasoil | 114.25 | 148.24 |
| Gas | 106.20 | 137.79 | Gas | 120.17 | 155.92 |

It is important to note that for the purpose of this sensitivity the comparison of PDCs is based on the incremental approach, that is approach labelled (b) and not on the total approach labelled (a). This is due to the fact that the total unit volume which also incorporates the load on the existing plant is not relevant for these specific simulations whereby the higher load on the interconnector results in an alteration of the relationship between the outputs of the plant.

## 5.2 Additional Sensitivity Analysis

*A higher load of electricity demand being first and foremost satisfied through the DPS extension*

This sensitivity scenario depicts the financial and economic impact of a higher electricity load on the DPS extension as opposed to the interconnector. The higher load, in effect, results in a lower PDC as well as a narrower difference between the financial and economic PDC of Gas and HFO. This is essentially due to the fact that the Gas scenario is characterised by high infrastructural costs which are of a fixed nature and therefore a higher load on the DPS extension would result in a lower cost on a per unit basis. This is evident from Table A15 below whereby the financial and economic PDC derived on the basis of incremental units that is the units associated with the extension, is lower under each of the fuel options compared to the baseline. It is interesting to note that from a financial perspective the difference between the PDC of Gas to HFO under the baseline at €22.50/MwH, falls to a narrower difference of

€10.42/MwH under this sensitivity scenario. Furthermore from an economic perspective, the Gas option renders the lowest PDC from an economic perspective.

**Chart A6: Sensitivity to demand being met by the DPS extension followed by the Interconnector**

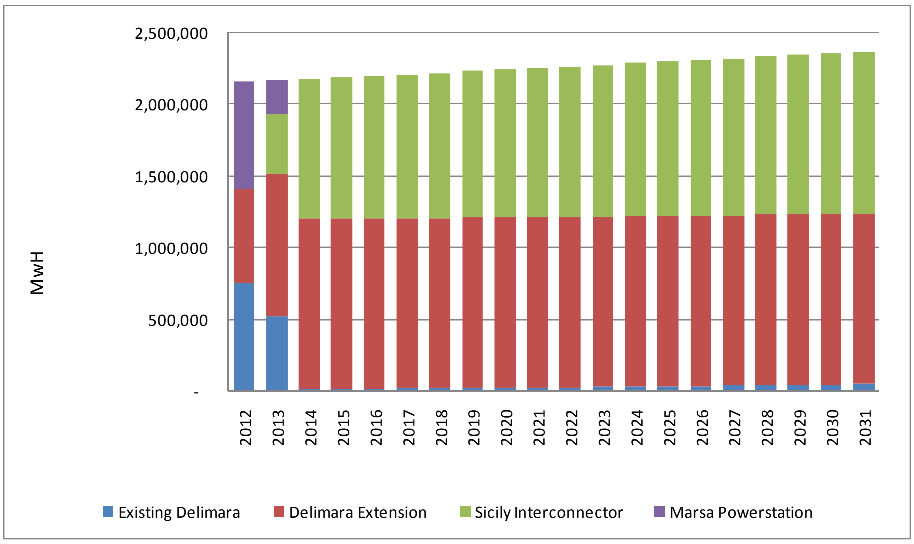



**Table A15: Sensitivity to Demand being met first and foremost by DPS Extension**

| Baseline | | | | | | |
|---|---|---|---|---|---|---|
| Financial | | | | Economic | | |
| | (a) PDC: Incremental Costs/Total Units (Existing and Extension) | (b) PDC: Incremental Costs/Incremental Units | | | (a) PDC: Incremental Costs/Total Units (Existing and Extension) | (b) PDC: Incremental Costs/Incremental Units |
| HFO | 82.94 | 99.31 | | HFO | 104.43 | 125.05 |
| Gasoil | 119.40 | 142.97 | | Gasoil | 132.36 | 158.49 |
| Gas | 101.73 | 121.81 | | Gas | 111.03 | 132.95 |
| Demand being met first and foremost by the DPS extension | | | | | | |
| Financial | | | | Economic | | |
| | (a) PDC: Incremental Costs/Total Units (Existing and Extension) | (b) PDC: Incremental Costs/Incremental Units | | | (a) PDC: Incremental Costs/Total Units (Existing and Extension) | (b) PDC: Incremental Costs/Incremental Units |
| HFO | 88.78 | 98.22 | | HFO | 111.64 | 123.51 |
| Gasoil | 128.96 | 142.67 | | Gasoil | 142.51 | 157.66 |
| Gas | 98.21 | 108.65 | | Gas | 106.48 | 117.80 |

Once again, it is important to note that for the purpose of this sensitivity the comparison of PDCs is based on the incremental approach, that is approach labelled (b) and not on the total approach labelled (a). This is due to the fact that the total unit volume which also incorporates the load on the existing plant is not relevant for these specific simulations whereby the change in pecking order results in an alteration of the relationship between the outputs of the plant.

### *A 10% increase in the price of $CO_2$ emission allowances*

An additional sensitivity scenario presented in this section of the addendum is the sensitivity of the financial results to a 10% increase in the price of $CO_2$ emission allowances. As can be seen from Table A15, the net financial position of HFO deteriorates by 1.17% followed by 0.78% in the case of Gasoil and 0.73% under the Gas scenario reflecting the level of emissions of each of the three scenarios. In terms of the switching value, the price of $CO_2$ emission allowances would have to increase almost nine fold for the financial feasibility of HFO to be entirely eroded and to match the net financial present value of Gas.

**Table A15: Sensitivity to a 10% increase in the price of $CO_2$ emission allowances**

| | Baseline: Price of CO2 allowances | | Scenario: 10% increase in the price of CO2 allowances | | Percentage Change | |
|---|---|---|---|---|---|---|
| | Financial | Economic | Financial | Economic | Financial | Economic |
| Scenario I (HFO+Gasoil) | 752,875,214 | 948,012,377 | 761,657,034 | 948,012,377 | 1.17% | 0.00% |
| Scenario II (Gasoil) | 1,083,851,490 | 1,201,503,148 | 1,092,252,155 | 1,201,503,148 | 0.78% | 0.00% |
| Scenario III (Gas) | 923,468,193 | 1,007,910,421 | 930,176,663 | 1,007,910,421 | 0.73% | 0.00% |
| | Financial | | | Economic | | |
| Baseline value | Price of CO2 allowances as established through Commission forecast | | | | | |
| Switching value | Price of CO2 allowances would have to increase almost nine fold. | | | | | |

6. Derivation of a Formula to allow for varying components of HFO and Gasoil use in the DPS Extension

This section of the report presents a formula to allow for varying proportions of HFO and Gasoil use in the DPS extension as requested by the Authority over the timeframe of the IPPC permit. The formula is derived from Scenario I presented throughout the report which effectively refers to the running of the DPS extension entirely on HFO while Scenario II refers to the running of the DPS extension entirely on Gasoil. These two scenarios represent the corner solutions of running the plant on either one of these fuels.

The PDC from a financial perspective, over a four year period, referred to as PDCF in the formulas presented hereunder, amounts to €79.39/MwH[12] under Scenario II that is running the entire plant on Gasoil. The PDC of the pure externality referred to as PDCE in the formulas below amounts to €33.69/MwH[13] under the Gasoil scenario. Both these costs represent the corner solution of running the DPS extension on Gasoil reflected by the point labelled Gasoil:1 in the chart. Similarly, the corner solution of running the DPS on HFO results in a PDCF of €79.39/MwH[14] and a PDC related to the externality of €42.60/MwH represented by the data point labelled HFO:1.

Based on this assessment a linear equation can be derived in terms of using varying proportions of HFO and Gasoil use in the DPS extension. The derivation of the formula is as follows:

$$PDCF = 111.54 - (79.39 - 111.54) * HFOprop \qquad \text{(c)}$$

$$PDCE = 33.69 + (42.60 - 33.69) * HFOprop \qquad \text{(d)}$$

[12] Refers to the net present value of the financial costs/incremental units (over the first four years of operation)
[13] Refers to the net present value of the externalities/ incremental units (over the first four years of operation)
[14] Refers to the net present value of the externalities/ incremental units (over the first four years of operation)

From Eq (c): $HFOprop = \frac{111.54 - PDCF}{32.15}$ (e)

From Eq (d): $HFOprop = \frac{PDCE - 33.69}{8.91}$ (f)

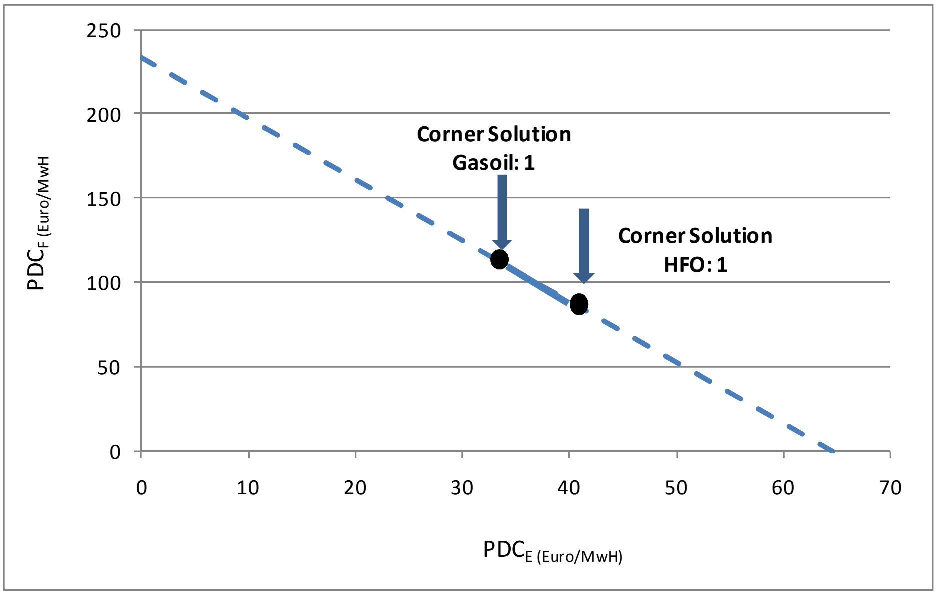
Therefore equating (e) and (f) : $\frac{111.54 - PDCF}{32.15} = \frac{PDCE - 33.69}{8.91}$

$$PDCE = 64.57 - 0.28PDCF$$

$$PDCF = 233.10 - 3.61PDCE$$

This implies that as one moves from the corner solution of 100% dependence on gasoil to a varying proportion of dependence on HFO, the PDC of the externality increases by €1/MwH while the financial PDC falls by €3.61/MwH. This in effect refers to the gradient of the slope and is due to the higher level of emissions related to the use of HFO compared to Gasoil as well as the lower overall cost of the fuel. Similarly a decrease in the pure externality cost of €1/MwH through higher dependence on Gasoil as opposed to HFO implies an increase of €3.61/MwH in the PDC from a financial perspective.

**Chart A7: Implication of varying proportions of HFO and Gasoil**




7. <u>Conclusion</u>

The introduction of $CO_2$ emission allowances and bag filters has increased the overall net present value of each of the scenarios and has narrowed the difference in the net present value of HFO compared to Gasoil and Gas. The relative ranking of the scenarios has remained unchanged and the main conclusions presented in the report remain unaltered.

To resummarise, the financial advantage of HFO continues to be robust to sensitivity assessments and actually improves significantly in the wake of energy efficiency in consumption, the utilisation of alternative energy sources and an increased reliance on inter-connection facilities. It weakens with an increased reliance on the extension as opposed to the interconnector and an increase in the price of crude oil as well as emission allowances but overall continues to remain the most financially feasible fuel.

The marginal economic advantage of HFO relative to Gas may be eroded by any one of the following conditions (everything else remaining the same):

- a 1% per annum increase in electricity demand;
- a 64% annual increase in crude oil prices;
- the relative price of gas to HFO declining from 110% to 92%;
- the investment in gas infrastructure being cheaper by 25%;
- a 41% increase in the shadow price of emissions.

The conclusion presented in the main report which indicates that a policy of flexibility in terms of the ability to use different types of fuel continues to be advised especially in light of the fact that the DPSE is projected to generate around 25% of Malta's energy requirements over the next twenty years, and will be required to supply energy for 85% of the time during a typical year. Its efficient operation will therefore be critical to the country's energy performance, from the financial and economic viewpoints.

In the short term, at least until 2015, the DPS extension cannot be run on gas due to the infrastructural adjustments required to operate the Plant. As a result during the time frame of the IPPC permit the extension can be run on HFO or Gasoil or varying proportions of the fuels. From a purely financial perspective HFO is more feasible with a lower PDC but it also renders a higher externality cost. Greater reliance on Gasoil would thus reduce the externality but also result in a higher financial PDC to the extent that a decrease in the pure externality cost of €1/MwH through higher dependence on Gasoil results in an increase in the financial PDC of €3.61/MwH.

# Annex A1: Detailed Results of the Financial Model

## Extension on HFO

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Operational and Maintenance** | | | | | | | | | | | | | | | | | | | | |
| Fuel Costs (HFO) | 32,204,684 | 50,970,820 | 27,628,561 | 29,099,782 | 30,749,858 | 32,414,964 | 34,195,017 | 36,081,498 | 38,089,250 | 40,115,818 | 42,246,375 | 44,593,818 | 46,942,306 | 49,441,612 | 52,102,059 | 54,819,026 | 57,645,080 | 60,622,696 | 63,811,351 | 67,146,404 |
| Lubricant oil cost | 957,292 | 1,515,120 | 821,266 | 864,998 | 914,047 | 963,543 | 1,016,455 | 1,072,532 | 1,132,213 | 1,192,453 | 1,255,784 | 1,325,562 | 1,395,372 | 1,469,664 | 1,548,747 | 1,629,509 | 1,713,514 | 1,802,025 | 1,896,808 | 1,995,944 |
| Urea Cost | 1,366,320 | 2,081,535 | 1,086,049 | 1,101,057 | 1,119,933 | 1,136,379 | 1,153,904 | 1,171,980 | 1,190,877 | 1,207,283 | 1,223,804 | 1,243,443 | 1,259,925 | 1,277,326 | 1,295,666 | 1,312,195 | 1,328,184 | 1,344,498 | 1,362,234 | 1,379,766 |
| Desox Reagent Cost | 1,736,132 | 2,697,828 | 1,435,754 | 1,484,707 | 1,540,363 | 1,594,243 | 1,651,205 | 1,710,613 | 1,772,959 | 1,833,332 | 1,895,588 | 1,964,528 | 2,030,379 | 2,099,590 | 2,172,330 | 2,244,043 | 2,316,815 | 2,392,177 | 2,472,209 | 2,554,107 |
| Maintenance Agreement | 3,508,554 | 4,512,683 | 3,102,383 | 3,123,718 | 3,150,287 | 3,174,320 | 3,198,903 | 3,224,485 | 3,251,163 | 3,274,134 | 3,297,400 | 3,324,995 | 3,348,354 | 3,372,884 | 3,398,636 | 3,421,910 | 3,444,849 | 3,467,783 | 3,492,858 | 3,517,734 |
| Maintenance personnel | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 |
| Waste Disposal | 2,017,708 | 3,073,900 | 1,603,819 | 1,625,982 | 1,653,857 | 1,678,144 | 1,704,023 | 1,730,718 | 1,758,624 | 1,782,851 | 1,807,248 | 1,836,251 | 1,860,590 | 1,886,287 | 1,913,370 | 1,937,779 | 1,961,391 | 1,985,482 | 2,011,674 | 2,037,565 |
| Operational Personnel | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 |
| Electricity to plant | 38,755 | 40,262 | 41,828 | 43,455 | 45,145 | 46,901 | 48,725 | 50,620 | 52,589 | 54,635 | 56,760 | 58,967 | 61,261 | 63,643 | 66,119 | 68,690 | 71,362 | 74,137 | 77,021 | 80,016 |
| Steam | 25,508 | 26,500 | 27,531 | 28,601 | 29,714 | 30,869 | 32,070 | 33,317 | 34,613 | 35,960 | 37,358 | 38,811 | 40,321 | 41,889 | 43,518 | 45,211 | 46,969 | 48,796 | 50,694 | 52,665 |
| SCR Regeneration disposal | - | - | - | - | - | 63,586 | - | - | - | - | 55,166 | - | - | - | - | 59,305 | - | - | - | - |
| Fabric Filters | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 |
| Emission Allowances (CO2) | 5,873,849 | 8,938,506 | 4,634,191 | 6,481,801 | 6,593,652 | 6,694,821 | 6,798,312 | 6,906,002 | 7,018,310 | 7,115,015 | 7,212,958 | 7,329,123 | 7,427,460 | 7,530,724 | 7,639,134 | 7,737,109 | 7,833,677 | 7,930,225 | 8,035,784 | 8,140,505 |
| **Total Operations and Maintenance Costs** | 49,228,039 | 75,766,392 | 41,880,619 | 45,763,338 | 47,296,093 | 49,707,009 | 51,297,852 | 53,891,002 | 55,799,834 | 58,520,718 | 60,587,678 | 63,624,735 | 65,865,204 | 69,092,856 | 71,678,815 | 75,184,014 | 77,861,077 | 81,577,057 | 84,709,870 | 88,813,943 |
| Min operations and Maintenance Costs | 49,228,039 | 75,766,392 | 41,880,619 | 45,763,338 | 47,296,093 | 49,707,009 | 51,297,852 | 53,891,002 | 55,799,834 | 58,520,718 | 60,587,678 | 63,624,735 | 65,865,204 | 69,092,856 | 71,678,815 | 75,184,014 | 77,861,077 | 81,577,057 | 84,709,870 | 88,813,943 |
| **Total Costs** | 49,228,039 | 75,766,392 | 41,880,619 | 45,763,338 | 47,296,093 | 49,707,009 | 51,297,852 | 53,891,002 | 55,799,834 | 58,520,718 | 60,587,678 | 63,624,735 | 65,865,204 | 69,092,856 | 71,678,815 | 75,184,014 | 77,861,077 | 81,577,057 | 84,709,870 | 88,813,943 |
| NPV | 752,875,214 € | | | | | | | | | | | | | | | | | | | |

## Extension on Gasoil

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Operational and Maintenance** | | | | | | | | | | | | | | | | | | | | |
| Fuel Costs (Gasoil) | 55,543,807 | 87,911,299 | 47,656,018 | 50,193,550 | 53,039,651 | 55,911,272 | 58,981,586 | 62,235,358 | 65,698,322 | 69,193,850 | 72,868,668 | 76,917,599 | 80,968,215 | 85,279,029 | 89,867,838 | 94,554,094 | 99,428,204 | 104,564,041 | 110,063,768 | 115,815,924 |
| Lubricant oil cost | 956,834 | 1,514,418 | 820,954 | 864,667 | 913,696 | 963,164 | 1,016,055 | 1,072,107 | 1,131,762 | 1,191,979 | 1,255,283 | 1,325,033 | 1,394,812 | 1,469,072.41 | 1,548,122.24 | 1,628,850.75 | 1,712,815.36 | 1,801,288.65 | 1,896,030.55 | 1,995,120.97 |
| Urea Cost | 1,365,595 | 2,080,462 | 1,085,580 | 1,100,578 | 1,119,444 | 1,135,874 | 1,153,390 | 1,171,456 | 1,190,342 | 1,206,741 | 1,223,253 | 1,242,882 | 1,259,354 | 1,276,746 | 1,295,076 | 1,311,597 | 1,327,573 | 1,343,879 | 1,361,605 | 1,379,126 |
| Desox Reagent Cost | 165,432 | 257,074 | 136,824 | 141,488 | 146,792 | 151,925 | 157,353 | 163,014 | 168,955 | 174,709 | 180,641 | 187,211 | 193,486 | 200,081 | 207,013 | 213,846 | 220,780 | 227,962 | 235,588 | 243,392 |
| Maintenance Agreement | 3,508,554 | 4,512,683 | 3,102,383 | 3,123,718 | 3,150,287 | 3,174,320 | 3,198,903 | 3,224,485 | 3,251,163 | 3,274,134 | 3,297,400 | 3,324,995 | 3,348,354 | 3,372,884 | 3,398,636 | 3,421,910 | 3,444,849 | 3,467,783 | 3,492,858 | 3,517,734 |
| Maintenance personnel | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 |
| Waste Disposal | 192,263 | 292,910 | 152,840 | 154,951 | 157,608 | 159,921 | 162,387 | 164,930 | 167,589 | 169,898 | 172,223 | 174,986 | 177,305 | 179,754 | 182,335 | 184,661 | 186,910 | 189,206 | 191,702 | 194,168 |
| Operational Personnel | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445.00 | 910,445.00 | 910,445.00 | 910,445.00 | 910,445.00 | 910,445.00 | 910,445.00 |
| Electricity to plant | 36,929 | 38,365 | 39,857 | 41,408 | 43,018 | 44,691 | 46,429 | 48,235 | 50,111 | 52,060 | 54,085 | 56,189 | 58,374 | 60,644.33 | 63,003.01 | 65,453.43 | 67,999.15 | 70,643.88 | 73,391.48 | 76,245.94 |
| Steam | 24,306 | 25,251 | 26,233 | 27,254 | 28,314 | 29,415 | 30,559 | 31,747 | 32,982 | 34,265 | 35,598 | 36,982 | 38,421 | 39,914.99 | 41,467.43 | 43,080.25 | 44,755.79 | 46,496.51 | 48,304.93 | 50,183.68 |
| SCR Regeneration disposal | - | - | - | - | - | 60,593 | - | - | - | - | 52,571 | - | - | - | - | 56,515 | - | - | - | - |
| Fabric Filters | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 |
| Emission Allowances CO2 | 5,618,907 | 8,550,550 | 4,433,054 | 6,200,473 | 6,307,469 | 6,404,248 | 6,503,246 | 6,606,263 | 6,713,695 | 6,806,204 | 6,899,895 | 7,011,018 | 7,105,087 | 7,203,869 | 7,307,575 | 7,401,297 | 7,493,673 | 7,586,031 | 7,687,009 | 7,787,185 |
| **Total Operations and Maintenance Costs** | 68,911,865 | 107,092,249 | 58,952,980 | 63,757,323 | 66,405,515 | 69,944,660 | 72,749,146 | 76,626,832 | 79,904,159 | 84,013,076 | 87,538,854 | 92,186,132 | 96,042,644 | 100,991,232 | 105,410,302 | 110,790,541 | 115,426,797 | 121,206,568 | 126,549,493 | 132,968,317 |
| **Total Costs** | 68,911,865 | 107,092,249 | 58,952,980 | 63,757,323 | 66,405,515 | 69,944,660 | 72,749,146 | 76,626,832 | 79,904,159 | 84,013,076 | 87,538,854 | 92,186,132 | 96,042,644 | 100,991,232 | 105,410,302 | 110,790,541 | 115,426,797 | 121,206,568 | 126,549,493 | 132,968,317 |
| NPV | 1,083,851,490 € | | | | | | | | | | | | | | | | | | | |

## Gas Option (Existing and Extension)

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Infrastructural Cost (Pipeline Option) | - | - | 273,621,846 | | | | | | | | | | | | | | | | | |
| Conversion of existing plant | - | - | 35,000,000 | | | | | | | | | | | | | | | | | |
| Residual | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - 113,161,344 |
| **Capital Costs** | - | - | 308,621,846 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - 113,161,344 |
| **Operational and Maintenance** | | | | | | | | | | | | | | | | | | | | |
| Fuel Costs | | | | 31,272,304 | 33,047,283 | 34,838,088 | 36,752,950 | 38,782,348 | 40,942,367 | 43,122,585 | 45,414,717 | 47,940,567 | 50,467,283 | 53,156,486 | 56,019,304 | 58,942,831 | 61,983,589 | 65,187,764 | 68,619,244 | 72,208,317 |
| Lubricant oil cost | | | | 790,558 | 835,429 | 880,700 | 929,107 | 980,410 | 1,035,015 | 1,090,130 | 1,148,075 | 1,211,928 | 1,275,803 | 1,343,785 | 1,416,157 | 1,490,063 | 1,566,933 | 1,647,934 | 1,734,681 | 1,825,412 |
| Urea Cost | | | | 1,128,285 | 1,147,687 | 1,164,584 | 1,182,600 | 1,201,181 | 1,220,608 | 1,237,477 | 1,254,463 | 1,274,657 | 1,291,603 | 1,309,496 | 1,328,356 | 1,345,355 | 1,361,794 | 1,378,573 | 1,396,814 | 1,414,845 |
| Desox Reagent Cost | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Maintenance Agreement | | | | 3,123,718 | 3,150,287 | 3,174,320 | 3,198,903 | 3,224,485 | 3,251,163 | 3,274,134 | 3,297,400 | 3,324,995 | 3,348,354 | 3,372,884 | 3,398,636 | 3,421,910 | 3,444,849 | 3,467,783 | 3,492,858 | 3,517,734 |
| Maintenance personnel | | | | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 |
| Waste Disposal | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Operational Personnel | | | | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 |
| Electricity to plant | | | | 30,511 | 31,698 | 32,931 | 34,212 | 35,542 | 36,925 | 38,361 | 39,853 | 41,403 | 43,013 | 44,686 | 46,424 | 48,230 | 50,106 | 52,054 | 54,079 | 56,182 |
| Steam | | | | 20,082 | 20,863 | 21,675 | 22,518 | 23,393 | 24,303 | 25,248 | 26,230 | 27,251 | 28,311 | 29,412 | 30,556 | 31,744 | 32,979 | 34,261 | 35,594 | 36,978 |
| SCR Regeneration disposal | | | | - | - | 60,593 | - | - | - | - | 52,571 | - | - | - | - | 56,515 | - | - | - | - |
| Emission Allowances CO2 | | | | 4,670,048 | 4,750,634 | 4,823,526 | 4,898,089 | 4,975,679 | 5,056,595 | 5,126,269 | 5,196,836 | 5,280,531 | 5,351,382 | 5,425,782 | 5,503,890 | 5,574,479 | 5,644,055 | 5,713,617 | 5,789,671 | 5,865,121 |
| **Total Operations and Maintenance Costs** | 49,228,039 | 75,766,392 | 41,880,619 | 42,534,742 | 44,483,119 | 46,495,653 | 48,517,616 | 50,722,276 | 53,066,212 | 55,413,442 | 57,929,382 | 60,600,568 | 63,304,985 | 66,181,768 | 69,242,560 | 72,410,364 | 75,583,541 | 78,981,224 | 82,622,178 | 86,423,826 |
| Net Savings in Operations and Maintenance Costs in runnning existing Delimara | - | - | - | 1,707,740 | 1,798,497 | 1,886,648 | 1,949,104 | 2,083,774 | 2,195,215 | 2,350,601 | 2,499,909 | 2,680,715 | 2,918,477 | 3,082,104 | 3,330,117 | 3,540,855 | 3,826,462 | 4,075,388 | 4,376,669 | 4,639,701 |
| **Total Costs** | 49,228,039 | 75,766,392 | 350,502,465 | 40,827,002 | 42,684,622 | 44,609,005 | 46,568,512 | 48,638,501 | 50,870,997 | 53,062,841 | 55,429,473 | 57,919,852 | 60,386,507 | 63,099,664 | 65,912,443 | 68,869,509 | 71,757,079 | 74,905,836 | 78,245,509 | - 31,377,219 |
| NPV | 923,468,193 € | | | | | | | | | | | | | | | | | | | |

# Annex 3: Detailed Results of the Economic (Incorporating Financial and Emissions) Model

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Extension on HFO** | | | | | | | | | | | | | | | | | | | | |
| **Operational and Maintenance** | | | | | | | | | | | | | | | | | | | | |
| Fuel Costs (HFO) | 32,204,684 | 50,970,820 | 27,628,561 | 29,099,782 | 30,749,858 | 32,414,964 | 34,195,017 | 36,081,498 | 38,089,250 | 40,115,818 | 42,246,375 | 44,593,818 | 46,942,306 | 49,441,612 | 52,102,059 | 54,819,026 | 57,645,080 | 60,622,696 | 63,811,351 | 67,146,404 |
| Lubricant oil cost | 957,292 | 1,515,120 | 821,266 | 864,998 | 914,047 | 963,543 | 1,016,455 | 1,072,532 | 1,132,213 | 1,192,453 | 1,255,784 | 1,325,562 | 1,395,372 | 1,469,664 | 1,548,747 | 1,629,509 | 1,713,514 | 1,802,025 | 1,896,808 | 1,995,944 |
| Urea Cost | 1,366,320 | 2,081,535 | 1,086,049 | 1,101,057 | 1,119,933 | 1,136,379 | 1,153,904 | 1,171,980 | 1,190,877 | 1,207,283 | 1,223,804 | 1,243,443 | 1,259,925 | 1,277,326 | 1,295,666 | 1,312,195 | 1,328,184 | 1,344,498 | 1,362,234 | 1,379,766 |
| Desox Reagent Cost | 1,736,132 | 2,697,828 | 1,435,754 | 1,484,707 | 1,540,363 | 1,594,243 | 1,651,205 | 1,710,613 | 1,772,959 | 1,833,332 | 1,895,588 | 1,964,528 | 2,030,379 | 2,099,590 | 2,172,330 | 2,244,043 | 2,316,815 | 2,392,177 | 2,472,209 | 2,554,107 |
| Maintenance Agreement | 3,508,554 | 4,512,683 | 3,102,383 | 3,123,718 | 3,150,287 | 3,174,320 | 3,198,903 | 3,224,485 | 3,251,163 | 3,274,134 | 3,297,400 | 3,324,995 | 3,348,354 | 3,372,884 | 3,398,636 | 3,421,910 | 3,444,849 | 3,467,783 | 3,492,858 | 3,517,734 |
| Maintenance personnel | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 |
| Waste Disposal | 2,017,708 | 3,073,900 | 1,603,819 | 1,625,982 | 1,653,857 | 1,678,144 | 1,704,023 | 1,730,718 | 1,758,624 | 1,782,851 | 1,807,248 | 1,836,251 | 1,860,590 | 1,886,287 | 1,913,370 | 1,937,779 | 1,961,391 | 1,985,482 | 2,011,674 | 2,037,565 |
| Operational Personnel | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 |
| Electricity to plant | 38,755 | 40,262 | 41,828 | 43,455 | 45,145 | 46,901 | 48,725 | 50,620 | 52,589 | 54,635 | 56,760 | 58,967 | 61,261 | 63,643 | 66,119 | 68,690 | 71,362 | 74,137 | 77,021 | 80,016 |
| Steam | 25,508 | 26,500 | 27,531 | 28,601 | 29,714 | 30,869 | 32,070 | 33,317 | 34,613 | 35,960 | 37,358 | 38,811 | 40,321 | 41,889 | 43,518 | 45,211 | 46,969 | 48,796 | 50,694 | 52,665 |
| SCR Regeneration disposal | - | - | - | - | - | 63,586 | - | - | - | - | 55,166 | - | - | - | - | 59,305 | - | - | - | - |
| Fabric Filters | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 |
| **Total Operations and Maintenance Costs** | 43,354,190 | 66,827,886 | 37,246,428 | 39,281,537 | 40,702,442 | 43,012,187 | 44,499,540 | 46,985,000 | 48,781,525 | 51,405,703 | 53,374,720 | 56,295,613 | 58,437,744 | 61,562,132 | 64,039,681 | 67,446,905 | 70,027,400 | 73,646,832 | 76,674,086 | 80,673,438 |
| Min operations and Maintenance Costs | 43,354,190 | 66,827,886 | 37,246,428 | 39,281,537 | 40,702,442 | 43,012,187 | 44,499,540 | 46,985,000 | 48,781,525 | 51,405,703 | 53,374,720 | 56,295,613 | 58,437,744 | 61,562,132 | 64,039,681 | 67,446,905 | 70,027,400 | 73,646,832 | 76,674,086 | 80,673,438 |
| **Total Financial Costs** | 43,354,190 | 66,827,886 | 37,246,428 | 39,281,537 | 40,702,442 | 43,012,187 | 44,499,540 | 46,985,000 | 48,781,525 | 51,405,703 | 53,374,720 | 56,295,613 | 58,437,744 | 61,562,132 | 64,039,681 | 67,446,905 | 70,027,400 | 73,646,832 | 76,674,086 | 80,673,438 |
| **Economic Costs** | | | | | | | | | | | | | | | | | | | | |
| CO2 emissions | 9,919,484 | 15,094,935 | 7,826,007 | 7,935,970 | 8,072,914 | 8,196,781 | 8,323,489 | 8,455,339 | 8,592,842 | 8,711,243 | 8,831,159 | 8,973,385 | 9,093,784 | 9,220,214 | 9,352,947 | 9,472,901 | 9,591,134 | 9,709,342 | 9,838,584 | 9,966,798 |
| Nox emissions | 4,651,480 | 7,078,371 | 3,669,799 | 3,721,364 | 3,785,580 | 3,843,664 | 3,903,080 | 3,964,908 | 4,029,387 | 4,084,908 | 4,141,139 | 4,207,832 | 4,264,290 | 4,323,576 | 4,385,817 | 4,442,067 | 4,497,509 | 4,552,940 | 4,613,544 | 4,673,667 |
| Sox emissions | 6,441,327 | 9,802,063 | 5,081,904 | 5,153,310 | 5,242,236 | 5,322,671 | 5,404,950 | 5,490,568 | 5,579,857 | 5,656,742 | 5,734,611 | 5,826,967 | 5,905,149 | 5,987,249 | 6,073,440 | 6,151,334 | 6,228,109 | 6,304,869 | 6,388,794 | 6,472,051 |
| Dust emissions | 6,453,437 | 9,820,492 | 5,091,459 | 5,162,999 | 5,252,092 | 5,332,677 | 5,415,111 | 5,500,891 | 5,590,348 | 5,667,377 | 5,745,392 | 5,837,922 | 5,916,251 | 5,998,505 | 6,084,858 | 6,162,898 | 6,239,818 | 6,316,723 | 6,400,805 | 6,484,219 |
| **Nh3** | 232,552 | 354,283 | 184,849 | 187,403 | 190,616 | 193,415 | 196,398 | 199,474 | 202,691 | 205,483 | 208,295 | 211,638 | 214,443 | 217,405 | 220,526 | 223,339 | 226,061 | 228,837 | 231,856 | 234,840 |
| **Arsenic** | 278,575 | 423,920 | 219,783 | 222,871 | 226,717 | 230,195 | 233,754 | 237,456 | 241,318 | 244,643 | 248,011 | 252,005 | 255,386 | 258,937 | 262,665 | 266,033 | 269,354 | 272,673 | 276,303 | 279,904 |
| **Cardmium** | 2,036 | 3,098 | 1,606 | 1,629 | 1,657 | 1,682 | 1,708 | 1,735 | 1,764 | 1,788 | 1,813 | 1,842 | 1,866 | 1,892 | 1,920 | 1,944 | 1,969 | 1,993 | 2,019 | 2,046 |
| **Total Economic Costs** | **27,978,889** | **42,577,163** | **22,075,407** | **22,385,545** | **22,771,811** | **23,121,085** | **23,478,490** | **23,850,373** | **24,238,206** | **24,572,185** | **24,910,419** | **25,311,591** | **25,651,170** | **26,007,778** | **26,382,172** | **26,720,518** | **27,053,954** | **27,387,378** | **27,751,905** | **28,113,525** |
| **Total Costs** | 71,333,079 | 109,405,049 | 59,321,834 | 61,667,082 | 63,474,253 | 66,133,272 | 67,978,030 | 70,835,373 | 73,019,731 | 75,977,887 | 78,285,139 | 81,607,203 | 84,088,914 | 87,569,910 | 90,421,853 | 94,167,423 | 97,081,354 | 101,034,210 | 104,425,991 | 108,786,962 |
| NPV | € 948,012,377 | | | | | | | | | | | | | | | | | | | |

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Extension on Gasoil** | | | | | | | | | | | | | | | | | | | | |
| **Operational and Maintenance** | | | | | | | | | | | | | | | | | | | | |
| Fuel Costs (Gasoil) | 55,543,807 | 87,911,299 | 47,656,018 | 50,193,550 | 53,039,651 | 55,911,272 | 58,981,586 | 62,235,358 | 65,698,322 | 69,193,850 | 72,868,668 | 76,917,599 | 80,968,215 | 85,279,029 | 89,867,838 | 94,554,094 | 99,428,204 | 104,564,041 | 110,063,768 | 115,815,924 |
| Lubricant oil cost | 956,834 | 1,514,418 | 820,954 | 864,667 | 913,696 | 963,164 | 1,016,055 | 1,072,107 | 1,131,762 | 1,191,979 | 1,255,283 | 1,325,033 | 1,394,812 | 1,469,072 | 1,548,122 | 1,628,851 | 1,712,815 | 1,801,289 | 1,896,031 | 1,995,121 |
| Urea Cost | 1,365,595 | 2,080,462 | 1,085,580 | 1,100,578 | 1,119,444 | 1,135,874 | 1,153,390 | 1,171,456 | 1,190,342 | 1,206,741 | 1,223,253 | 1,242,882 | 1,259,354 | 1,276,746 | 1,295,076 | 1,311,597 | 1,327,573 | 1,343,879 | 1,361,605 | 1,379,126 |
| Desox Reagent Cost | 165,432 | 257,074 | 136,824 | 141,488 | 146,792 | 151,925 | 157,353 | 163,014 | 168,955 | 174,709 | 180,641 | 187,211 | 193,486 | 200,081 | 207,013 | 213,846 | 220,780 | 227,962 | 235,588 | 243,392 |
| Maintenance Agreement | 3,508,554 | 4,512,683 | 3,102,383 | 3,123,718 | 3,150,287 | 3,174,320 | 3,198,903 | 3,224,485 | 3,251,163 | 3,274,134 | 3,297,400 | 3,324,995 | 3,348,354 | 3,372,884 | 3,398,636 | 3,421,910 | 3,444,849 | 3,467,783 | 3,492,858 | 3,517,734 |
| Maintenance personnel | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 |
| Waste Disposal | 192,263 | 292,910 | 152,840 | 154,951 | 157,608 | 159,921 | 162,387 | 164,930 | 167,589 | 169,898 | 172,223 | 174,986 | 177,305 | 179,754 | 182,335 | 184,661 | 186,910 | 189,206 | 191,702 | 194,168 |
| Operational Personnel | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 |
| Electricity to plant | 36,929 | 38,365 | 39,857 | 41,408 | 43,018 | 44,691 | 46,429 | 48,235 | 50,111 | 52,060 | 54,085 | 56,189 | 58,374 | 60,644 | 63,003 | 65,453 | 67,999 | 70,644 | 73,391 | 76,246 |
| Steam | 24,306 | 25,251 | 26,233 | 27,254 | 28,314 | 29,415 | 30,559 | 31,747 | 32,982 | 34,265 | 35,598 | 36,982 | 38,421 | 39,915 | 41,467 | 43,080 | 44,756 | 46,497 | 48,305 | 50,184 |
| SCR Regeneration disposal | - | - | - | - | - | 60,593 | - | - | - | - | 52,571 | - | - | - | - | 56,515 | - | - | - | - |
| Fabric Filters | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 | - | 410,000 |
| **Total Operations and Maintenance Costs** | 63,292,958 | 98,541,699 | 54,519,926 | 57,556,850 | 60,098,046 | 63,540,412 | 66,245,900 | 70,020,570 | 73,190,464 | 77,206,872 | 80,638,959 | 85,175,114 | 88,937,557 | 93,787,362 | 98,102,728 | 103,389,244 | 107,933,123 | 113,620,536 | 118,862,484 | 125,181,132 |
| **Total Financial Costs** | 63,292,958 | 98,541,699 | 54,519,926 | 57,556,850 | 60,098,046 | 63,540,412 | 66,245,900 | 70,020,570 | 73,190,464 | 77,206,872 | 80,638,959 | 85,175,114 | 88,937,557 | 93,787,362 | 98,102,728 | 103,389,244 | 107,933,123 | 113,620,536 | 118,862,484 | 125,181,132 |
| **Economic Costs** | | | | | | | | | | | | | | | | | | | | |
| CO2 emissions | 9,488,950 | 14,439,772 | 7,486,336 | 7,591,527 | 7,722,527 | 7,841,018 | 7,962,226 | 8,088,354 | 8,219,889 | 8,333,151 | 8,447,862 | 8,583,915 | 8,699,088 | 8,820,032 | 8,947,003 | 9,061,751 | 9,174,852 | 9,287,930 | 9,411,562 | 9,534,211 |
| Nox emissions | 6,441,327 | 9,802,063 | 5,081,904 | 5,153,310 | 5,242,236 | 5,322,671 | 5,404,950 | 5,490,568 | 5,579,857 | 5,656,742 | 5,734,611 | 5,826,967 | 5,905,149 | 5,987,249 | 6,073,440 | 6,151,334 | 6,228,109 | 6,304,869 | 6,388,794 | 6,472,051 |
| Sox emissions | 2,325,740 | 3,539,186 | 1,834,900 | 1,860,682 | 1,892,790 | 1,921,832 | 1,951,540 | 1,982,454 | 2,014,693 | 2,042,454 | 2,070,569 | 2,103,916 | 2,132,145 | 2,161,788 | 2,192,909 | 2,221,034 | 2,248,755 | 2,276,470 | 2,306,772 | 2,336,833 |
| Dust emissions | 3,872,062 | 5,892,295 | 3,054,875 | 3,097,799 | 3,151,255 | 3,199,606 | 3,249,067 | 3,300,535 | 3,354,209 | 3,400,426 | 3,447,235 | 3,502,753 | 3,549,751 | 3,599,103 | 3,650,915 | 3,697,739 | 3,743,891 | 3,790,034 | 3,840,483 | 3,890,531 |
| Nh3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Arsenic | | | | | | | | | | | | | | | | | | | | |
| Cardmium | | | | | | | | | | | | | | | | | | | | |
| **Total Economic Costs** | **22,128,079** | **33,673,317** | **17,458,016** | **17,703,318** | **18,008,808** | **18,285,126** | **18,567,783** | **18,861,911** | **19,168,648** | **19,432,773** | **19,700,278** | **20,017,551** | **20,286,133** | **20,568,171** | **20,864,266** | **21,131,858** | **21,395,607** | **21,659,303** | **21,947,610** | **22,233,627** |
| **Total Costs** | 85,421,037 | 132,215,016 | 71,977,941 | 75,260,168 | 78,106,854 | 81,825,538 | 84,813,683 | 88,882,481 | 92,359,112 | 96,639,646 | 100,339,237 | 105,192,665 | 109,223,690 | 114,355,533 | 118,966,994 | 124,521,101 | 129,328,730 | 135,279,840 | 140,810,095 | 147,414,759 |
| NPV | € 1,201,503,148 | | | | | | | | | | | | | | | | | | | |

## Gas Option (Existing and Extension)

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Infrastructural Cost (Pipeline Option) | - | - | 273,621,846 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Conversion of existing plant | - | - | 35,000,000 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Residual | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - 113,161,344 |
| **Capital Costs** | - | - | 308,621,846 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - 113,161,344 |
| **Operational and Maintenance** | | | | | | | | | | | | | | | | | | | | |
| Fuel Costs | - | - | - | 31,272,304 | 33,047,283 | 34,838,088 | 36,752,950 | 38,782,348 | 40,942,367 | 43,122,585 | 45,414,717 | 47,940,567 | 50,467,283 | 53,156,486 | 56,019,304 | 58,942,831 | 61,983,589 | 65,187,764 | 68,619,244 | 72,208,317 |
| Lubricant oil cost | - | - | - | 790,558 | 835,429 | 880,700 | 929,107 | 980,410 | 1,035,015 | 1,090,130 | 1,148,075 | 1,211,928 | 1,275,803 | 1,343,785 | 1,416,157 | 1,490,063 | 1,566,933 | 1,647,934 | 1,734,681 | 1,825,412 |
| Urea Cost | - | - | - | 1,128,285 | 1,147,687 | 1,164,584 | 1,182,600 | 1,201,181 | 1,220,608 | 1,237,477 | 1,254,463 | 1,274,657 | 1,291,603 | 1,309,496 | 1,328,356 | 1,345,355 | 1,361,794 | 1,378,573 | 1,396,814 | 1,414,845 |
| Desox Reagent Cost | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Maintenance Agreement | - | - | - | 3,123,718 | 3,150,287 | 3,174,320 | 3,198,903 | 3,224,485 | 3,251,163 | 3,274,134 | 3,297,400 | 3,324,995 | 3,348,354 | 3,372,884 | 3,398,636 | 3,421,910 | 3,444,849 | 3,467,783 | 3,492,858 | 3,517,734 |
| Maintenance personnel | - | - | - | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 | 588,792 |
| Waste Disposal | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Operational Personnel | - | - | - | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 | 910,445 |
| Electricity to plant | - | - | - | 30,511 | 31,698 | 32,931 | 34,212 | 35,542 | 36,925 | 38,361 | 39,853 | 41,403 | 43,013 | 44,686 | 46,424 | 48,230 | 50,106 | 52,054 | 54,079 | 56,182 |
| Steam | - | - | - | 20,082 | 20,863 | 21,675 | 22,518 | 23,393 | 24,303 | 25,248 | 26,230 | 27,251 | 28,311 | 29,412 | 30,556 | 31,744 | 32,979 | 34,261 | 35,594 | 36,978 |
| SCR Regeneration disposal | - | - | - | - | - | 60,593 | - | - | - | - | 52,571 | - | - | - | - | 56,515 | - | - | - | - |
| **Total Operations and Maintenance Costs** | 43,354,190 | 66,827,886 | 37,246,428 | 37,864,694 | 39,732,484 | 41,672,127 | 43,619,527 | 45,746,597 | 48,009,618 | 50,287,173 | 52,732,547 | 55,320,037 | 57,953,603 | 60,755,986 | 63,738,670 | 66,835,884 | 69,939,486 | 73,267,607 | 76,832,507 | 80,558,705 |
| Savings in Operations and Maintenance Costs in runnning existing Delimara | - | - | - | 1,593,845 | 1,676,186 | 1,756,946 | 1,872,920 | 2,000,968 | 2,107,893 | 2,256,369 | 2,399,743 | 2,573,271 | 2,801,101 | 2,959,745 | 3,198,735 | 3,403,152 | 3,679,263 | 3,921,252 | 4,213,794 | 4,470,566 |
| **Total Financial Costs** | 43,354,190 | 66,827,886 | 345,868,274 | 36,270,849 | 38,056,298 | 39,915,181 | 41,746,607 | 43,745,629 | 45,901,725 | 48,030,804 | 50,332,804 | 52,746,766 | 55,152,502 | 57,796,241 | 60,539,934 | 63,432,732 | 66,260,223 | 69,346,355 | 72,618,713 | - 37,073,205 |
| Economic Costs | | | | | | | | | | | | | | | | | | | | |
| CO2 emissions | - | - | - | 5,717,756 | 5,816,422 | 5,905,667 | 5,996,958 | 6,091,954 | 6,191,023 | 6,276,330 | 6,362,727 | 6,465,199 | 6,551,945 | 6,643,036 | 6,738,668 | 6,825,094 | 6,910,279 | 6,995,446 | 7,088,563 | 7,180,940 |
| Nox emissions | - | - | - | 2,603,219 | 2,648,140 | 2,688,772 | 2,730,335 | 2,773,586 | 2,818,691 | 2,857,530 | 2,896,865 | 2,943,520 | 2,983,014 | 3,024,486 | 3,068,026 | 3,107,375 | 3,146,158 | 3,184,934 | 3,227,329 | 3,269,387 |
| SO2 emissions | | | | | | | | | | | | | | | | | | | | |
| Dust emissions | - | - | - | 1,408,091 | 1,432,389 | 1,454,367 | 1,476,849 | 1,500,243 | 1,524,640 | 1,545,648 | 1,566,925 | 1,592,161 | 1,613,523 | 1,635,956 | 1,659,507 | 1,680,790 | 1,701,769 | 1,722,743 | 1,745,674 | 1,768,423 |
| Nh3 | | | | | | | | | | | | | | | | | | | | |
| Arsenic | | | | | | | | | | | | | | | | | | | | |
| Cardmium | | | | | | | | | | | | | | | | | | | | |
| Total Economic Costs | 27,978,889 | 42,577,163 | 22,075,407 | 9,729,065 | 9,896,951 | 10,048,805 | 10,204,142 | 10,365,784 | 10,534,355 | 10,679,508 | 10,826,518 | 11,000,879 | 11,148,481 | 11,303,479 | 11,466,201 | 11,613,259 | 11,758,206 | 11,903,123 | 12,061,566 | 12,218,750 |
| Net Savings in Economic Costs | | | | 219,735 | 235,971 | 250,231 | 272,785 | 296,499 | 312,668 | 337,411 | 358,657 | 384,718 | 420,280 | 438,122 | 470,428 | 493,061 | 527,065 | 551,905 | 583,194 | 605,608 |
| **Net Economic Costs** | **27,978,889** | **42,577,163** | **22,075,407** | **9,509,330** | **9,660,980** | **9,798,574** | **9,931,357** | **10,069,284** | **10,221,686** | **10,342,097** | **10,467,860** | **10,616,161** | **10,728,201** | **10,865,357** | **10,995,773** | **11,120,198** | **11,231,141** | **11,351,218** | **11,478,372** | **11,613,141** |
| **Total Costs** | 71,333,079 | 109,405,049 | 367,943,681 | 45,780,179 | 47,717,278 | 49,713,755 | 51,677,963 | 53,814,913 | 56,123,411 | 58,372,900 | 60,800,664 | 63,362,927 | 65,880,704 | 68,661,598 | 71,535,707 | 74,552,930 | 77,491,364 | 80,697,573 | 84,097,085 | - 25,460,063 |
| NPV | € 1,007,910,421 | | | | | | | | | | | | | | | | | | | |