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Downstream oil - short term resilience and longer term security of supply.

Final Report for DECC

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Contents

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Executive Summary

Background

The UK demand for oil products has changed over the last 10 to 15 years, driven by growth in the aviation sector, the increasing number of diesel vehicles in the UK and a reduction in the use of oil for power generation. Although aggregate demand has only fallen slightly – the 2008 total of about 76 million tonnes (**“mt”**) is around 2mt below the level of the late 1990s – there has been a significant shift in the mix of products consumed.

UK refineries have been unable to match the changing pattern of demand. Compared to current UK demand, domestic refineries produce a surplus of gasoline and fuel oil and relatively little middle distillates, as they are still configured to meet the historically higher levels of gasoline demand. Shortfalls in diesel/gas oil are primarily covered by imports from Russia, the Netherlands and Sweden, and aviation fuel shortfalls are primarily covered by imports from Kuwait, Singapore, India and Venezuela. At the same time, surpluses of gasoline are exported to North America. The UK is expected to become increasingly dependent on imports of middle distillates as changes in the demand mix continue. For refineries to re-configure their processes to produce more diesel and less gasoline, substantial investment would be required in new processing/conversion units of up to £700m at each major refinery.

At the same time, additional factors are contributing to the significant financial and competitive pressures facing the UK refining sector. Future margins are expected to weaken, due to factors such as the expected slow growth in demand, increasingly stringent environmental standards and fuel efficiency legislation and the increased use of ethanol in the US which may threaten gasoline exports to the US. This may make it uneconomic to invest in upgrading UK refineries to match changing demand patterns or to process different crude oils. It may also lead to further refinery closures beyond the significant rationalisation which the industry has already undergone.

Scope of this report

As part of its responsibility to ensure the UK’s energy supplies are reliable, secure, and of adequate quality and scale to meet expected future demand, the Department of Energy and Climate Change (“**DECC**”) has commissioned a study on oil security of supply and the resilience of the downstream oil sector to supply interruptions. This study addresses two main questions.

- Should the Government be concerned about the UK becoming more dependent on imported refined oil products together with the associated closure of UK refineries?
- Given the risks and potential impacts of physical supply interruptions what should be the policy response of the Government?

Our approach

We have used the analysis of a number of representative supply interruption scenarios to assess the potential impact of refinery closures on security of supply and resilience. We have also examined the wider economic implications of refinery closures beyond any impact on security of supply. Our work is based on the following steps.

- **Supply-demand scenarios**. We have developed a number of scenarios for the future UK supply and demand balance for crude oil and petroleum products. This includes the definition of a base and low scenario for the UK's refining capacity. The 'base refining' scenario takes the existing capacity of the eight major UK refineries at the start of 2010, with a nameplate capacity of around 1.7mbd. The 'low refining' scenario assumes a 27% reduction in this capacity (equivalent to around 1.24mbd) by assuming that two refineries shut down before 2015. We have also examined a base and high demand case, based on DECC analysis.

- **Oil supply chain analysis**. We have examined the key components of the UK's oil supply chain, both for crude and for oil products, and identified the time-lags and quantities in transit through each of the key supply routes. We used this information to overlay the supply interruption scenarios described in the next step and to support the analysis on potential mitigating options in each case.

- **Interruption scenarios**. We have developed a number of scenarios to test the resilience provided by domestic refining capacity in the event of a supply interruption. We have selected interruptions which would have a significant effect on the UK, either due to the disruption of supply from a key trading partner or by impacting a producer of wider significance to global crude or product market. We discuss the selected interruption scenarios in more detail below.

- **Resilience drivers and realised impact of interruption**. We have identified a range of mitigating actions that can be used to compensate for a supply interruption and minimise the potential impact on consumers. These are outlined in more detail below. We then assessed the extent to which these mitigating actions may reduce the impact of the interruption scenarios under analysis. This allowed us to draw conclusions on the implications of a change in future level of UK refining capacity for the effectiveness of the mitigating actions and the consequent impact of the interruption.

- **Wider cost benefit analysis**. We have examined some of the key sources of wider economic benefit or cost associated with refineries, beyond the security of supply benefits, in order to understand the wider economic implications of refinery closures.

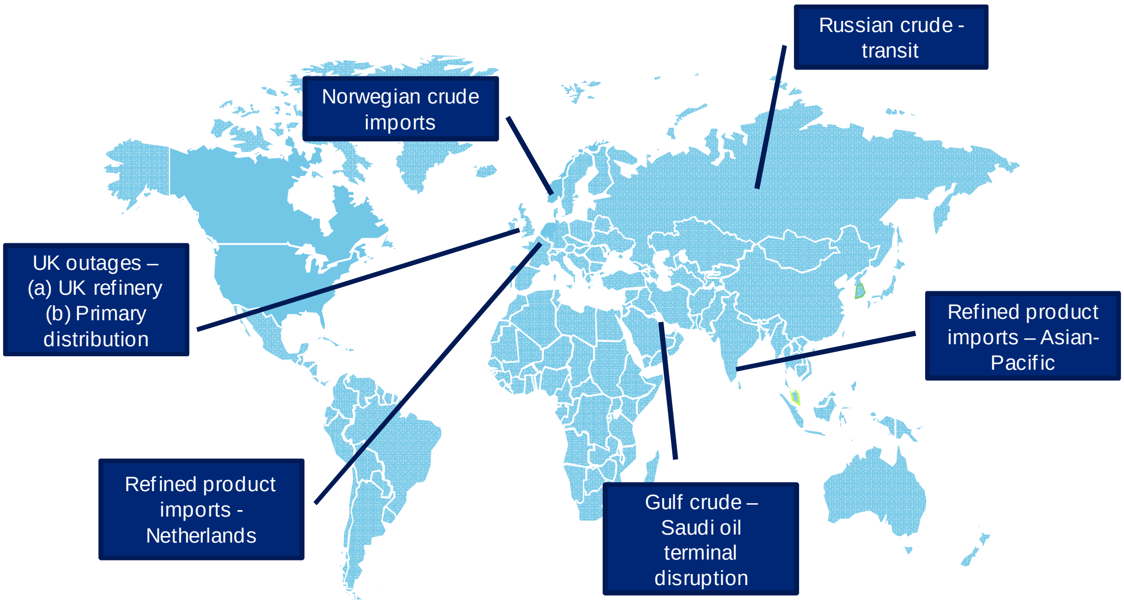
Interruption scenarios and realised impact

We have looked at seven representative interruption scenarios, which are intended to highlight the relative implications of base and low levels of refining capacity for security of supply and resilience. These scenarios do not constitute an exhaustive set of possible interruptions. These are illustrated in the figure below.

While we have selected interruptions with a significant impact on the UK, we have deliberately avoided analysing catastrophic interruption scenarios (such as a blockade of the Strait of Hormuz which could remove up to 40% of all globally traded oil supply, representing a loss of 20% of world demand). Such catastrophic interruptions would have negative effects on both crude and product markets, and therefore offer fewer insights into the relative advantages of domestic refining capacity and product imports. Furthermore, there are few policy options available to mitigate against a very significant interruption. The key mitigation – at least for a short-term interruption – is a co-ordinated release of emergency stocks via the IEA emergency response mechanism.

We have therefore focussed our analysis on less dramatic interruption scenarios, although we have also examined the benefits of domestic refining capacity in the event of a complete disruption to world markets.

Figure 1: Supply interruption scenarios



We summarise the key features of each interruption in the table below. Although we have specified some distinct causes of each interruption for the purposes of our analysis, there are a number of alternative scenarios which could lead to disruptions of similar magnitude. The indicative probability of interruption is intended to represent the probability of a disruption of this magnitude occurring, rather than the probability of the specific incident occurring. These probabilities need to be treated with considerable caution: they have not been estimated and constitute only an assumed probability for the purpose of comparative analysis within the context of this report. Further work would be required to validate or improve these probability assumptions.

Table 1: Summary of interruption scenarios

Interruption	Description	Total volumes disrupted			Disruption duration (days)	Assumed probability
		2008	2015	2030		
Norwegian crude exports	Pump failure on Norpipe pipeline to UK	660mbd	510mbd	330mbd	180	1 in 30 years
Russian crude exports	Interruption to pipeline leading to Baltic port of Primorsk	1mbd	1mbd	1.3mbd	21	1 in 10 years
Indian aviation fuel exports	Reliance refinery outage	6.8kt/day	6.8kt/day	6.8kt/day	180	1 in 10 years
Saudi crude exports	Export terminal interruption	1mbd	1mbd	1mbd	180	1 in 5 years
Rotterdam diesel/gas oil exports	Shipping incident leading to port closure	29kt/day	29kt/day	29kt/day	21	1 in 10 years
UK domestic refinery	Fawley refinery outage	266kbd processing capacity			21	1 in 10 years
UK aviation fuel import terminal	Shipping incident at Bristol Aviation Fuel terminal	3.3kt/day	3.3kt/day	3.3kt/day	21	1 in 10 years

The realised impact of each interruption scenario depends on the extent to which mitigating actions can offset the interruption. We have applied a framework for assessing the realised impact of an interruption in terms of volumes, duration and price effects (see Section 4.1 for further detail). We have considered the ability of a range of mitigating actions to compensate for the initial interruption and reduce the final impact on UK consumers. These include:

- availability of spare global crude production capacity;
- access to alternative crude supplies in terms of market transparency and ability to process the available grade;
- spare capacity in UK refineries and ability to flex product yields;
- diversion of domestic production of crude or product which would otherwise have been exported;
- availability of spare global refining capacity;
- access to alternative product supplies in terms of market transparency and appropriateness of available product specification;
- availability of shipping capacity;
- number, capacity and flexibility of entry points to the UK;
- utilisation of inventory and stocks, taking into account the fact that some product market interruptions may require particular product stocks; and

- demand management.

Findings from our scenario analysis

The scale of interruption in our scenarios in the context of the global market and current spare capacity, both in crude production and refining capacity, is not sufficiently large to cause a physical disruption. However, there would be some substantial price impacts immediately following the disruption, which would then be reduced to some extent over the duration of the interruption. For example, in the case of an interruption to Norwegian crude supplies, there is a potential immediate price increase of around 30% following the interruption.

Given an immediate impact on prices, we would expect world markets to adjust and respond to price changes caused by the interruption. Therefore, we expect that the UK would be able to obtain stocks to replace interrupted volumes, albeit at a price premium compared to the pre-interruption prices. We would anticipate some short term rigidities as the market adjusts and as such the UK may not be able to fully replace supplies immediately after a disruption. However, existing crude and product stocks can be used during this short-term period to cover any potential short-fall due to these rigidities in the market. In particular, in the event of a major international disruption of oil supplies, the IEA would be expected to co-ordinate a collective release of emergency stocks from its 26 member countries to offset the impacts of the supply disruption.

There is currently spare crude and refining capacity at a global level. In the case of a disruption, the UK should be able to access this spare capacity provided that the market is still responding to price signals. The extent to which this spare capacity is available in the future will depend on global trends in the balance of supply and demand in crude and refining capacity.

The above conclusions are based on the assumption that oil markets function sufficiently well over the period of a disruption, with prices being allowed to move freely to reflect the relative scarcity of the disrupted product and to incentivise a market response. On the basis of this assumption, the UK would be able to meet demand for the duration of the interruptions we have examined by a combination of using stocks and accessing global markets.

In general, UK refineries enhance downstream oil resilience by providing a number of additional options to manage a potential supply disruption. This includes diversity in terms of the sources of supply for crude oil to the UK.

Furthermore, under certain circumstances – such as much larger supply interruptions or a breakdown in markets for products – having a refining base and some degree of self-sufficiency in the production of refined products does have an additional value. In the event of a bottleneck in global refining capacity followed by a lack of response by refined product markets, or if oil or product markets cease to function following political intervention or a major conflict, having UK refineries together with appropriately sourced crude production enables the UK to maintain a greater proportion of domestically refined products. A stylised “complete self-sufficiency” scenario indicates that domestic refining capacity could provide additional value of around £260bn per year, given complete market breakdown. We have not been asked to look at these circumstances in detail. However, we note that UK refineries do have some limitations even in more extreme circumstances, such as:

- inflexibility in UK refineries to use a more sour crude slate as an alternative to light crude during a crude interruption, given that a significant proportion of spare capacity is in Saudi Arabia and is of a more sour variety;

- limited surplus conversion capacity to increase crude runs and middle distillate production in response to a product disruption, assuming that UK refineries are maximising their middle distillate production to meet UK demand; and

- reduced ability to match UK product demand, particularly for diesel, given the existing refining yield structure as the demand for products in the UK has changed towards middle distillates.

In the context of wider economic benefits, UK refineries provide additional benefits in three key areas.

- **Employment benefits**. Although refinery workers would be likely to find alternate employment in the absence of the refining sector (under Green Book assumptions of full employment), refineries jobs appear to offer a considerable productivity premium over various comparator industries. This could be up to £270m per year depending on the comparator used.

- **Lower storage costs**. Refineries provide the option to use crude oil stocks to meet the UK's CSO. A reduction in refinery capacity is likely to lead to a higher proportion of stocks being held as products, which is more expensive than storing crude. If all crude stocks needed to be replaced by product stocks, one-off investment costs could be in the region of £1.32bn to £1.56bn.

- **Wider spillover effects to industry**. Petrochemical plants, power plants and heavy industry tend to locate near to refineries to minimise cost of accessing fuels. This clustering effect may generate knowledge spillover benefits and thereby increase productivity. While there is no reason to expect that a replacement import terminal would be unable to supply the profile of refined products that the local industry cluster requires, knowledge spillovers from the complex operations at the refinery would be lost.

Key conclusions

Should the Government be concerned about becoming more import dependent on oil products?

The changing pattern of demand has led to a mismatch between UK refining capacity and demand. This has resulted in a supply-demand imbalance in middle distillates, and in particular for low-sulphur diesel and aviation fuel. This imbalance is expected to increase over the next 10 to 15 years as demand for diesel and aviation fuel grows from current levels as described in Section 2.3. This imbalance is set to be more significant under high demand growth scenarios.

Existing UK refineries are unlikely to address this imbalance given the scale of investment required to build additional conversion capacity to increase yields of middle distillate products (£450m-£700m per refinery for additional hydrocracker capacity). Therefore, the UK is likely to become more import dependent for diesel and aviation fuel over the period to 2020. The extent of import dependency will increase with any further refinery closures.

An increased dependency on imports of refined products may raise concerns relating to resilience and security of supply. However, a number of trends over the last decade are likely to minimise these concerns. This includes growth in trade in oil products, a move towards greater standardisation of certain products and new refining capacity being brought online with the intention of targeting export markets.

However, we note that a higher proportion of future refined product imports may come from a small number of countries or regions, in particular from India and Middle Eastern countries such as Saudi Arabia and Kuwait. This is partly due to European refiners being subject to the same financial and competitive pressures as UK refiners, which makes further capacity expansion in Europe unlikely. A reliance on fewer sources may leave the UK more exposed to a disruption from a single source than is currently the case.

Why is UK refinery capacity expected to decrease while new capacity comes online elsewhere?

A number of countries, notably in the Middle East and Asia are increasing their refining capacity, which is being supported by a number of key drivers:

- **Demand growth.** Expected future growth in demand for refined products as economies develop and oil consumption per capita increases.
- **Industrialisation.** To develop an industrial base and support economic growth and development of skilled employment.
- **Diversification.** Desire to diversify economy from dependence of crude oil production to higher value added services such as refined products. This is a key driver for increases in capacity in the Middle East.
- **Government support.** Certain countries have attracted foreign investment by providing support to new refineries.
- **Economies of scale.** Larger, more complex refineries are being constructed given technological developments in refining and economies of scale (capacity for new refineries ranges from 400-600kbd, compared to existing UK refineries which average around 210kbd). With lower unit costs compared to older existing refineries, refined products can be exported to other markets (such as Europe) at competitive prices.

The UK is in a different situation to a number of these countries which limits the opportunities for new refining capacity to be built and in fact may lead to closures of UK refineries.

- The UK has an existing refining capacity base that meets part of its demand for oil products. However, some of this refining capacity is ageing and less efficient compared to other European refineries and even more when compared to new refineries being built in Asia.

- UK refineries are operated by commercially sensitive companies that respond to changes in market prices by adjusting production levels. These companies operate in a global market and will locate their capital investments to deliver the highest returns.

- UK is seen as a mature market, with minimal growth in overall oil product demand, although there is a shift in the demand by types of products (reduction in gasoline and fuel oil demand but growth in diesel and aviation fuel).

- The UK's planning and consent rules can deter new investment in the UK given the potential time that may be required to obtain planning permission for large scale industrial projects.

- The number of oil terminals around the UK, proximity of UK to European refining capacity and the main European trading hub for refined products (Rotterdam) means that the UK is well located to import products by sea and to supply its inland regions.

Should the Government be worried about the changing patterns of refinery ownership?

Changing ownership in UK refineries in part reflects the reorganisation of portfolios by major oil companies. With excess refining capacity in Europe, together with a mature product market, international oil companies are rationalising their refining capacity in Europe as margins are hit by lower demand and competition from imported products. Many of these companies are instead looking for opportunities in new and growing markets to maximise returns on their investment.

With only a single UK refinery in the top quartile for North West Europe based on gross margins, UK refineries are likely to be considered in plans to rationalise excess refining capacity in North West Europe. For example, Shell announced in August 2009 that it was considering a sale of its Stanlow refinery in the UK, as well as two German refineries at Heide and Harburg.

Given the increased market liquidity and transparency seen over the last decade or so for both crude and product markets, vertically integrated ownership of the supply chain does not necessarily mean better access to crude oil. Therefore, access to supplies is likely to be available to any participant in the market that is willing and able to pay the market price.

However, a number of refineries are owned by independent refinery companies, some of which have high gearing ratios. Typically, vertically integrated oil companies have greater financial capability and are not as highly leveraged in comparison to some independent refiners. In the event of a supply disruption, companies that are highly leveraged may have greater difficulty in accessing additional funds that may be required to purchase products as prices rise during a disruption. Therefore, the financial position of a company may affect the ability to acquire product rapidly at the time of a disruption, which is likely to be an issue both for refiners and for importers.

Should the Government be concerned about refinery closures in the UK?

UK refineries enhance downstream oil resilience by providing a number of additional options to manage a potential supply disruption. This includes diversity in terms of supply sources for crude oil to the UK and the location of crude stocks close to refineries.

However, in the context of the types of interruptions analysed, the contribution of UK refineries to the resilience of the UK downstream oil market is limited by a number of factors. These include:

- a limited ability for UK refineries to use sourer grades of crude and maintain product yields (although there is growing light sweet crude production capacity, sufficient to offset the decline in North Sea production, UK refineries' limited ability to process sourer grades of crude reduces flexibility in the context of an interruption to light sweet crude supplies);

- limited surplus conversion capacity to increase crude runs and middle distillate production in response to a product disruption; and

- reduced ability to match UK product demand given the existing refining yield structure.

Furthermore, the UK is not shown to be any less vulnerable to a domestic interruption due to a refinery outage than to an import terminal outage. A highly utilised pipeline and primary distribution system means that the ability to mitigate an interruption at any ingress point by diverting flows to other points may be constrained.

However, certain circumstances will enhance the value of UK refining capacity in terms of resilience and overall security of supply, subject to the limitations highlighted previously. These are:

- a global refining bottleneck, where there is spare capacity for crude production but constraints for refined products;

- international markets ceasing to function due to political intervention at the time of a disruption; and

- continued access to light sweet crude supplies during a disruption for UK refineries to maintain product quality and yields.

Policy recommendations

Based on our key findings, we have identified a number of areas that could enhance resilience and security of supply. We set out below some particular actions and areas for further analysis that the Government may wish to consider further.

How can downstream oil resilience be enhanced?

There are a number of ways in which downstream oil resilience could be enhanced. However, there is clearly a trade-off between the cost of developing additional resilience and the additional benefit delivered in the event of a supply disruption.

Crude supplies. There are two main options for enhancing resilience in the event of an interruption to light sweet crude supply. The first option is to make UK refineries more flexible through investment in desulphurisation capacity at UK refineries. However, the investment is likely to cost between £260m to £440m per refinery to implement and refiners may be reluctant to make this level of investment in the face of low refinery margins, excess refinery capacity in North West Europe and potential opportunities to make higher returns on investments elsewhere. The second option is to build broader and deeper economic and political relationships with the countries exporting light sweet crude oil supplies to the UK. The main future suppliers of light sweet crude to the UK are commercially driven, with oil being sold primarily on a spot basis. Therefore, supplies are unlikely to be secured through long-term contracts and there may be limited scope to secure preferential access to supplies in the event of a disruption. But this may be mitigated to some extent through relationship building.

Access to product supplies. Our analysis has concluded that the liquidity in global oil markets offer the potential to mitigate against product supply disruptions. The move towards standardisation of products has contributed to the liquidity and depth of product markets, and consequently to the volumes which can be accessed in the event of a disruption from a particular source. Downstream oil resilience can therefore be enhanced by ensuring that UK product demand is for standard product specifications so that the UK is able to access the full depth of global product markets.

Storage capacity. Resilience and security of supply could be further enhanced by having more refined products in storage. We note that the level of emergency stocks required to be kept by the UK is expected to increase in light of the UK's declining oil production. This shift in storage requirements could occur as early as 2016. However, this may be expensive, with estimates of £220-£260/tonne for the capital investment required to build new storage facilities. Under the current oil stocking framework, the companies themselves would need to meet this additional level of stocks and would seek to do so at minimum cost. Consequently, a higher proportion of product stocks could be located abroad if companies find it cheaper than building new storage in the UK. This may have an impact on the UK's resilience to local disruptions, or to disruptions which affect access to the stocks held in other countries. The Government should keep the location of stocks under close review.

Managed transition to increased import dependency. There is clearly a transition period that will be undertaken by the UK as it moves towards greater import dependency, with associated changes in the UK's downstream oil infrastructure. This could introduce some constraints in supply unless managed appropriately.

- **Increased demand**. The UK represents a relatively large consumer, and a sudden shift from domestic refining capacity to product imports – for example, if several refineries were to close in the space of a few years – could conceivably have a price impact on the global market for refined products. The extent of price increases would depend on the level of spare capacity and the aim should be to manage the transition to avoid large impacts on prices. We note, however, that simultaneous closures are unlikely and the reduction in capacity caused by the closure of a refinery increases margins and makes it less likely that others will close.

- **Jetty facilities**. Product tankers are generally considerably smaller than crude tankers. This means that additional investment in the discharge facilities at jetties may be required in order to accommodate the smaller vessels.

- **Waterway ship handling capacity**. Smaller product ships means that more shipping will be required to service a given amount of UK demand with product imports than with crude imports for domestic production. This has implications for ship handling infrastructure, such as the number of tugs and tug pilots and the monitoring of traffic in waterways.

Ensuring a managed and gradual transition will be important to prevent any supply disruptions due to temporary rigidities in the system.

What are possible actions for government and areas for further work?

Given the above considerations, there are a number of actions that the Government may take to enhance the UK's downstream oil resilience. We have six key recommendations for further work to better understand the required policy response from government.

1. Managing the transition towards greater import dependency.

The transition towards greater import dependency may be accompanied by logistic and supply constraints, particularly if this happens over a short period of time. The Government can work together with industry to support and facilitate this transition in a number of ways, including the following.

- **Requiring a notice period for full refinery closure.** This could reduce a potential import capacity bottleneck by avoiding simultaneous refinery closures.
- **Limiting use of former refinery sites.** This would reserve the potential use of refinery facilities for product imports in the event of a refinery closure.
- **Mothballing of refineries for a limited period after closure.** This would provide the potential for the refinery to be brought back on line if supply and logistical constraints became apparent after closure. This option is only available for a limited period of time – less than one year – as long-term mothballing severely compromises the condition of the refinery.

2. Review wider global trends in capacity

As agreed with DECC, our work has looked at the UK resilience and security of supply, taking global capacity for crude and refinery as a given. Our findings indicate that the UK could become more reliant on global supplies to meet its demands and as such further work on the likely trends in global refining capacity is required.

Our work has only included a high-level analysis of broader trends in North-West Europe and the rest of the world, and the UK position in the context of these trends. Further work is required to understand the dependencies between the UK's transition towards greater import levels and a possible similar transition across Europe as a whole. This should include an assessment of how the global market will develop in the light of supply/demand trends and the policies of governments.

Work should also be undertaken to examine the potential for bottlenecks in the wider global refining market. Multiple refinery closures in a relatively short space of time may lead to increased tightness in global markets if new capacity additions elsewhere do not compensate for the increased demand in the required timescales. This will depend on broader market trends.

3. Access to markets

We have suggested that downstream oil resilience can be enhanced by ensuring that UK product demand is for standard product specifications, so that the UK is able to access the full depth of global product markets. This implies that Government policy, in as much as it affects product specifications, should be aligned with prevailing policy at least in the EU and possibly with other markets such as the US. The Government should consider the implications of future policy changes on product specifications and work with other bodies to ensure that changes are not made unilaterally.

4. Changing storage requirements

The increased volumes of emergency stocks required as a result of the UK's declining oil production, combined with the shift from crude to product stocks as product imports increase and refining capacity is potentially reduced, will require a response from obligated companies. Companies may choose to locate these stocks outside the UK through bi-lateral agreements rather than building new storage in the UK. More work is needed to understand the likely response of obligated companies to increased product storage requirements. This can be taken in the context of whether the existing model will provide the correct incentives for companies to invest in UK storage and the likely impacts of this on regional resilience to supply disruptions.

5. Financeability

Our key conclusions rely on the assumption that oil markets continue to function and that crude and products are available at the prevailing market price. Therefore, one area of potential action outside of the oil market is around financeability and working capital at the time of a supply disruption. More work is required to understand how market participants finance their operations, and the timescales and criteria for accessing commercial credit. The outcome of this may imply that the Government should look at ways of making short-term credit facilities available to companies supplying the UK to ensure that refined products can be purchased at the market price in the event of a supply disruption. This would minimise the potential risk that could be faced by companies if prices were to rise and could not extend their credit facilities to cover working capital requirements.

6. Minimum security of supply arrangements in the event of market breakdown

As agreed with DECC, our work has considered the implications for security of supply of a reduction in refining capacity equivalent to two refineries. Government should also consider what, if any, is the minimum level of refining capacity that should be maintained as insurance against market breakdown. Further work in this area might include an estimate of the baseline level of refining capacity required for the UK to be broadly self-reliant in an emergency situation. This could be developed under a number of scenarios for short-term austerity measures, such as a three day week, with key workers and emergency services operating at current levels. This baseline level of refining would need to be in line with the UK's broader energy strategy and aims to reduce carbon emissions.

1 Introduction

As part of its responsibility to ensure the UK's energy supplies are reliable, secure, and of adequate quality and scale to meet expected future demand, the Department of Energy and Climate Change ("**DECC**") has commissioned a study on oil security of supply and the resilience of the downstream oil sector to supply interruptions to address two main questions.

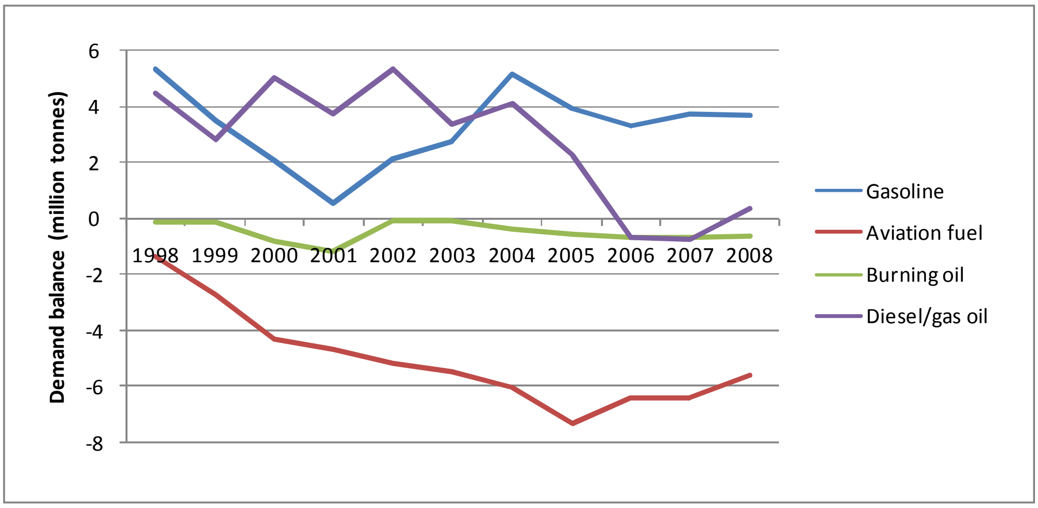
- Should the Government be concerned about the UK becoming more dependent on imported refined oil products together with the associated closure of UK refineries?
- Given the risks and potential impacts of physical supply interruptions what should be the policy response of the Government?

1.1 Background

The UK demand for oil products has changed over the last 10 to 15 years, driven by growth in the aviation sector, increasing number of diesel vehicles in the UK and a reduction in the use of oil for power generation. Although overall demand trends have shown only slight shrinkage – the 2008 total of about 76 million tonnes (**"mt"**) is around 2mt below the level of the late 1990s – there has been a discernable shift in the pattern of products demanded.

The consumption of gasoline has declined due to an intensifying move towards dieselisation in motor fuels usage, while demand for aviation fuel has risen as a result of increased air travel. Domestic burning oil shows relative stability over this period. The net effect of changing demand pattern has significantly increased the weighting of UK consumption towards middle distillates, a tendency which has been seen across North-West Europe as a whole. The increasing imbalance between product demand and domestic production of refined products by UK refineries is shown in Figure 2 below.

Figure 2: Balance between UK demand and domestic production for petroleum products



Source: DECC, Digest of UK Energy Statistics; Deloitte analysis
Note: Negative demand balance means the UK domestic production is less than demand.

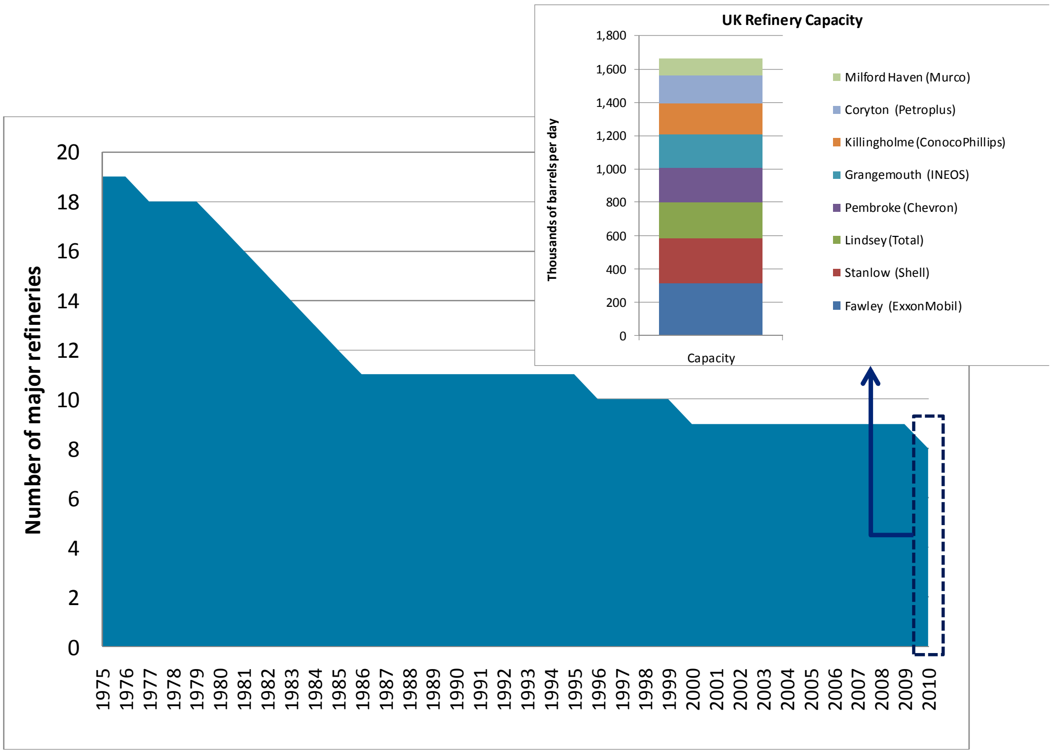
Compared to current UK demand, domestic refineries produce a surplus of gasoline and fuel oil and relatively little aviation fuel as they are still configured to meet the historically higher levels of gasoline demand (and in general are not ideally designed to match the current UK and north-west European product profile). Shortfalls in diesel/gas oil and aviation fuel are covered by imports from Russia, the Middle East and Asia-Pacific, while surpluses of gasoline are exported to North America.

The increasing use of biofuels will exacerbate an existing over-supply of gasoline in the UK. This could make the future of UK refineries increasingly dependent on the US gasoline market. For refineries to re-configure their output to produce more diesel and less gasoline, substantial investment would be required in new processing/conversion units. Increasing diesel output by upgrading the "bottom of the barrel" residues such as fuel oil will require a typical investment of between £440m and £700m per refinery for "hydrocracker" upgrading.[1]

Changes to the UK refining sector

The UK refining sector has undergone significant rationalisation in recent years. Notably, the number of major refineries in the UK has fallen from a high of 19 in 1975 to just eight in operation at the start of 2010 (Figure 3), with further consolidation increasingly likely.

Figure 3: Number and ownership of UK refineries



Source: UKPIA

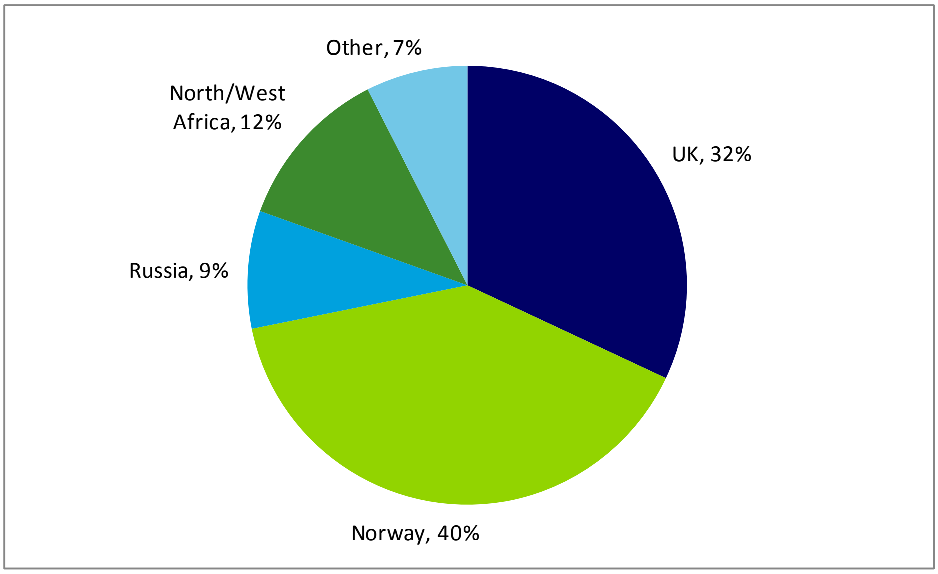
[1] Industry sources. Based on an estimate of between €500m and €800m.

In addition to changes in demand for oil products, the rationalisation in refining is occurring in response to a number of additional pressures in the refining industry.

Declining North Sea production

The decline in UK North Sea production has led to increasing levels of import dependency, with the UK becoming a net importer of crude oil since 2005. UK refineries now obtain only 32% of crude oil from UK production, with the remainder coming predominantly from Norway, Russia and Africa, as shown in Figure 4 below.

Figure 4: UK refinery crude supply by source (2008)



Source:DECC, Digest of UK Energy Statistics

Regulatory requirements

Meeting tighter product specifications requires refiners to increase processing and upgrading to, among other things, reduce sulphur content of products to meet EC IV and V emissions requirements. This may require investment in new units and refinery expansions to increase desulphurisation. The units needed are major investments and take several years to plan and build. Furthermore, environmental standards for refineries are becoming more stringent. It is likely that gas oil sulphur levels will be reduced from 1000ppm to 50ppm or 10ppm in the future, with a similar reduction expected for aviation fuel. Similarly, stretch targets might be adopted in the UK under the implementation of the Renewable Energy Directive which will require use of hydrogenated vegetable oil to be added to diesel. Recent changes to the MARPOL Annex VI regulations to reduce harmful emissions from ships by reducing sulphur levels in marine fuel oil will also impact refiners. All these measures will place further pressure on the hydro-desulphurisation capacity of UK refineries. Additional regulatory pressures include the EU ETS, which may result in higher costs for UK refineries in comparison to some other international refineries if allowances are auctioned instead of freely allocated.

Loss of market share in end user market

The large integrated oil companies with refining interests have lost market share to independent traders in some end user markets, especially as a result of the aggressive price cutting in motor fuel by the supermarkets. The loss of motor fuels retailing market share has been accompanied by a severe rationalisation in retail networks. For example, the number of service stations in the UK has declined from around 14,000 in 1998 to just over 9200 at the end of 2008.[2] The refiner marketers have also pursued rationalisation strategies in other sectors of the business, especially in the distribution of bulk fuels, in the domestic, commercial and industrial sectors.

Increasing competition

The IEA expects that investment in new refining capacity in other regions, such as the Middle East, India and Africa, will substantially outpace investment in Europe. Additional primary distillation capacity complemented by new conversion capacity and desulphurisation capacity will enable countries in those regions to increase exports of refined products to European markets. The complexity and scale of the new refinery capacity (the capacity of some new Middle Eastern and Indian refineries is as high as 600 thousand bpd compared to typical existing refineries of about 150 thousand bpd in Europe) is likely to provide a competitive advantage over UK refineries.

Summary

In summary, the UK refining sector is under significant financial and competitive pressure. Future margins are expected to weaken, due to factors such as the expected slow growth in demand, additional environmental costs including CO_2, and fuel efficiency legislation and the increased use of ethanol in the US which may threaten gasoline exports to the US. This may make it uneconomic to invest in upgrading refineries to match changing patterns of demand or to process different crude oils.

At the same time the UK is becoming increasingly dependent on certain imported oil products as expected future growth in demand for middle distillates cannot be met through production at UK refineries. These two trends set the background to this study.

1.2 Scope of Report

The scope of work that is required to respond to the two key questions from DECC has the following important components.

- Understanding the relative implications for security of supply of crude vs. product import dependence.
- Assessing the impact of refinery closures on import dependency and security of supply.
- Identifying the resilience drivers for the UK in the context of physical interruptions.

[2] UKPIA, 2009 Statistical Review, p27

- Assessing the impact of physical interruptions on consumers and economic activity.
- Reviewing whether there is a case for the Government to take action to improve the UK's security of supply.

The remainder of the Report is organised as follows.

- **Section 2** discusses the balance of UK demand and supply for crude and oil products. Section 2.1 and Section 2.2 examine the demand for and supply of crude oil and refined products, respectively, reviewing current and expected indigenous production and trends in imports. Section 2.3 presents scenarios of crude and refined product supply and demand in 2015 and 2030, which we use as the basis for our analysis.
- **Section 3** examines the UK's oil supply chain. In Section 3.1 and Section 3.2, we present a mapping of the crude and refined product chains to UK refinery or UK import terminals, identifying the time-lags and quantities in transit through each of the key supply routes. Section 3.3 discusses the primary and secondary distribution channels to the final consumer.
- **Section 4** defines scenarios of the key security of supply risks. Section 4.1 provides an overview of our analytical framework, discussing the nature, impact and likelihood of a range of supply interruptions. In Section 4.2, we present a selection of interruption scenarios which will be the focus of more detailed analysis.
- **Section 5** considers a range of mitigating actions to limit the impact of supply interruptions, and assesses possible constraints which might reduce the effectiveness of these mitigating actions.
- **Section 6** analyses the impact of the interruption scenarios presented in Section 4, taking into account the ability of relevant mitigating actions to limit the duration and magnitude of interruption.
- **Section 7** summarises the conditions under which the UK refineries benefit resilience and security of supply.
- **Section 8** considers the wider costs and benefits of refineries, in addition to security of supply benefits.
- **Section 9** concludes, summarising the key conclusions from our analysis and the resulting policy implications.

2 The UK's supply-demand positioning for crude and oil products

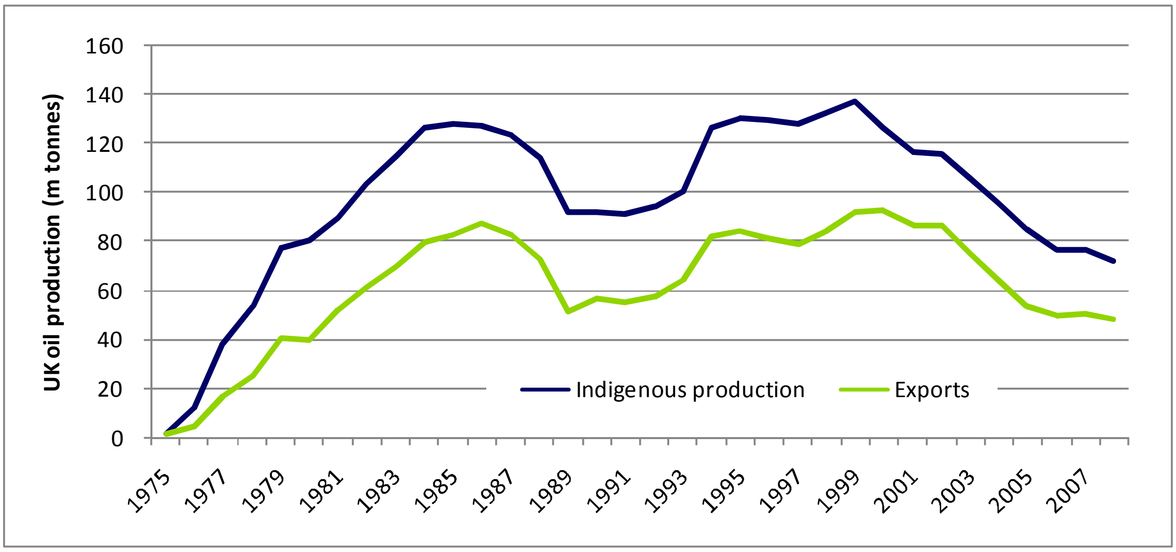
This section provides historical data on the supply and demand position for crude and oil products in the UK. It then sets out a number of potential supply-demand balance for products and crude oil for 2015 and 2030 to be used in the analysis of potential supply disruptions. This forms the basis for the range of scenarios we have constructed to assess the potential benefits to resilience and security of supply of having domestic refining capacity.

2.1 Crude supply-demand

2.1.1 UK oil production

The UK developed its indigenous oil production in the early 1970s with the discovery and development of oil fields in the North Sea. As shown in Figure 5, a significant proportion of the UK's oil production has been exported. UK oil production peaked in 1999 and has been in decline since then. The rate of decline has varied between years, with an average rate of decline of 7% between 1999 and 2008. In more recent years, the rate of decline has slowed to around 5.4% per annum between 2005 and 2008.

Figure 5: UK oil production 1975 to 2008 (million tonnes)

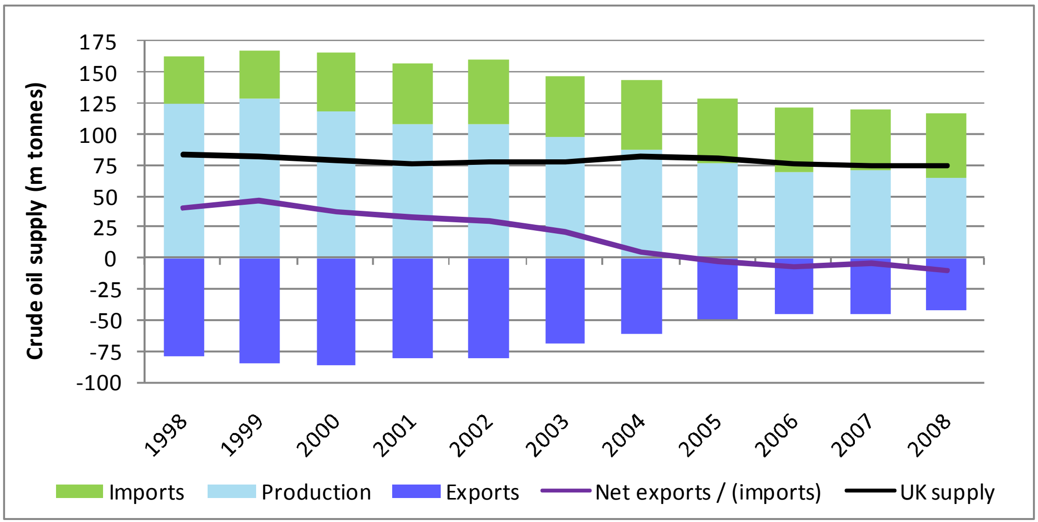


Source: Digest of UK Statistics, 2009; Note: figures include natural gas liquids production

2.1.2 Crude demand and net position

The driver for crude oil demand in the UK is the refinery intake for the production of petroleum products. Up until 2005, the UK was a net exporter of oil with production from the North Sea exceeding the domestic crude oil requirements. The UK currently exports around two-thirds of its crude oil production, with the volumes of exports changing broadly in line with the decline in production.

Figure 6: UK crude oil supply 1998 to 2008 (million tonnes)

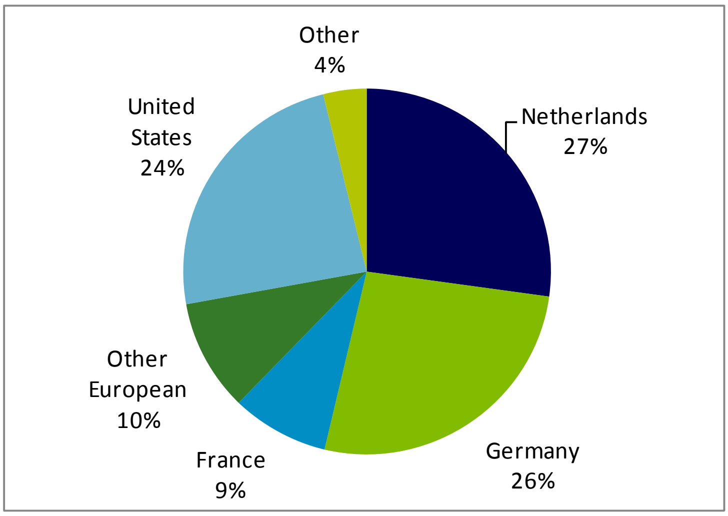


Source: Digest of UK Statistics, 2009; Note: figures exclude natural gas liquids production

2.1.3 Exports

The main export markets for UK crude oil are European countries and the USA. Over 70% of UK crude oil production in 2008 was exported to Europe, with the Netherlands and Germany importing around 11mt of crude oil from the UK. The USA was also a significant UK export market with nearly 10mt of crude in 2008.

Figure 7: UK Crude Exports, 2008 – 41.3mt

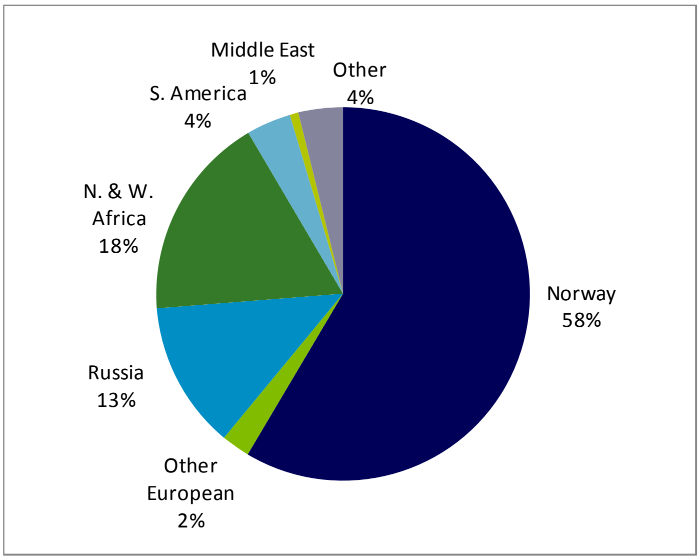


Source: International Energy Agency

2.1.4 Sources of imports

As well as exporting its own crude, the UK imports crude from overseas to meet its requirements and for commercial reasons. The UK will increasingly rely on imports as UK crude production declines, assuming a constant UK demand for crude. The source of imports is mainly driven by the type of crude required by UK refineries, which primarily use North Sea crude which is a lighter and sweeter crude variety. As such, the large majority of crude imports are from Norway (58% in 2008), with some of the Norwegian fields having a direct link to the UK via pipelines in the North Sea (for example Norpipe coming into Teesside processing terminal). Figure 8 shows the sources of UK imports in 2008, with Russia (13%) and North and West African countries[3] (18%) being the most significant. Less than 1% of imports are from the Middle East as this type of crude tends to be heavier and sourer than North Sea crude and the proportion of this type of crude used in the crude feed is limited by yield considerations and the need to control sulphur levels in finished products, refinery intermediates and emissions.

Figure 8: Sources of UK crude oil imports, 2008 – 51.5mt



Source: International Energy Agency

2.1.5 Rest of world potential developments

The UK's future crude supply-demand balance is set against a longer-term decline in non-OPEC oil production. In particular, the decline in UK and Norwegian crude production will lead to the UK and other European countries to source crude imports from alternative sources. The ability to meet this in the future will be driven by two elements.

Crude demand growth

The extent of future demand growth is uncertain, but the main areas for growth are likely to be in non-OECD countries, namely China, Asia, Middle East and Latin America. The latest IEA World Energy Outlook suggests that global oil demand is estimated to rise from 84.7mbd in 2008, to 105.2mbd by 2030.[4] This is primarily driven by growth in non-OECD economies, where demand is projected to rise from 36mbd to 57mbd over the same period. This is mainly due to economic

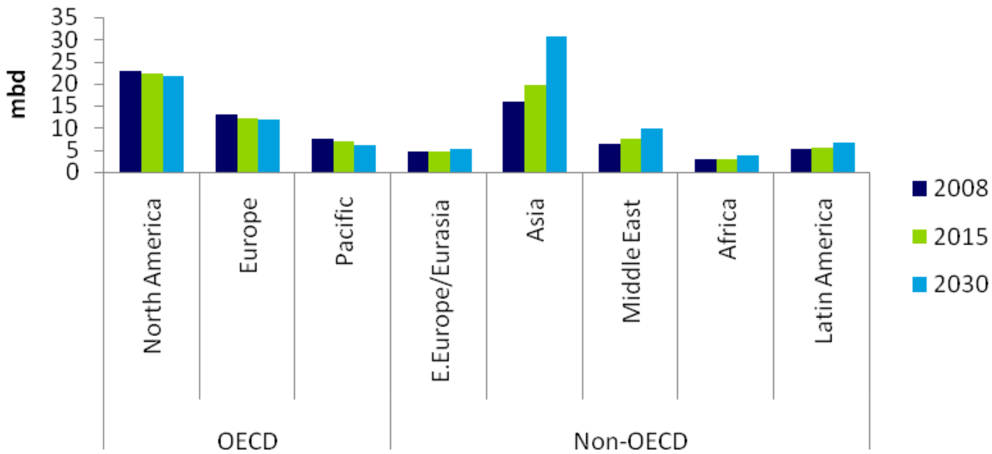
[3] This includes crude imports from Nigeria, Angola, Libya and Algeria

[4] IEA World Energy Outlook 2009

development of the major non-OECD economies such as China and India, and in particular growing demand for transport fuels. In 2009 China became the largest vehicle market with 13.5m cars and light trucks sold compared with 10.4m in the US.

In contrast, the OECD is forecast to experience a small decline in demand (-0.3%) from 2008 to 2030. We note that these demand projections are based on the IEA Reference Case Scenario, which provides a baseline of how energy markets may evolve with no further changes in government policy. The adoption of policies favouring energy efficiency and emissions abatement will cause demand to grow at slower rates.

Figure 9: Projected Demand, by region

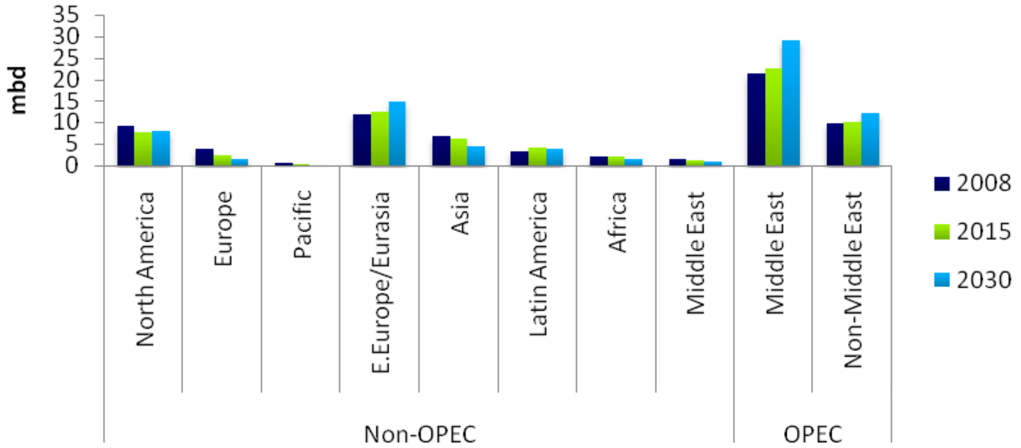


Source: IEA World Energy Outlook 2009

Crude oil supply

Growth in crude production capacity is expected to be centred in the Caspian and OPEC production countries over the next 10 to 20 years. While a number of projects are expected to begin production over the next few years, medium term production capacity will be dependent on what happens to future demand growth.

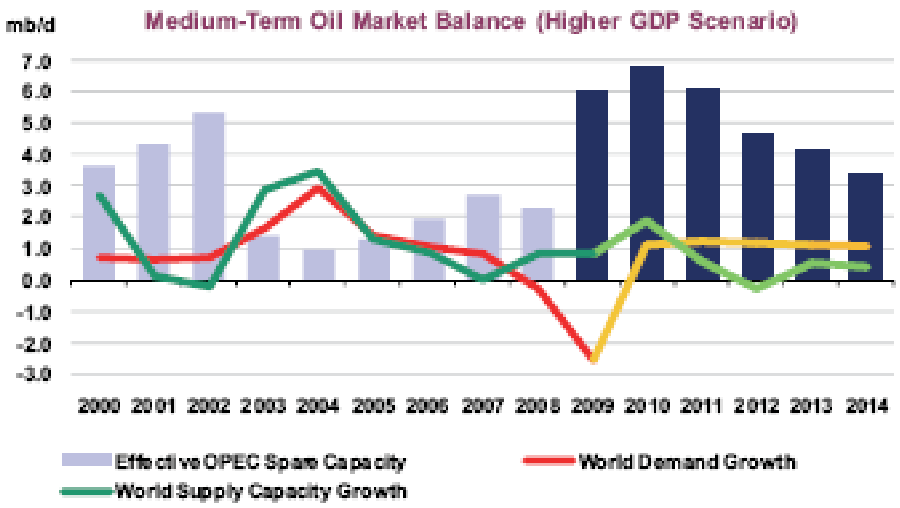
Figure 10: Crude Oil Production Projections

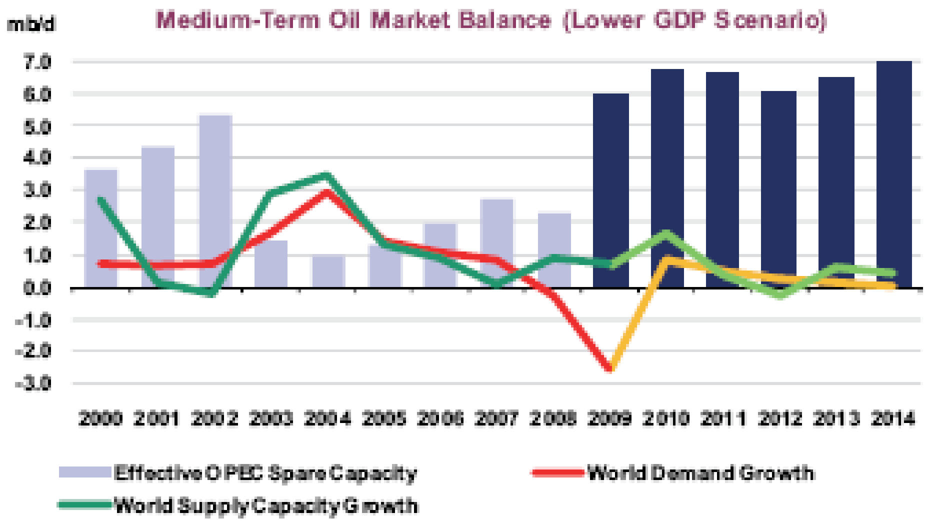


Source: IEA World Energy Outlook 2009

The level of spare oil production capacity over the next five years will be determined by future demand for oil and growth in new capacity. There is significant uncertainty about future growth of demand following the decreases seen in 2009. The IEA's Medium Term Outlook includes two scenarios covering higher and lower GDP growth assumptions. The main difference between these two scenarios relates to OPEC effective spare capacity by 2014. Under the lower GDP growth scenario, the level of spare capacity to respond to unexpected supply shocks is likely to be greater than that seen in the last five years. In the higher GDP growth scenario, the level of spare capacity by 2014 would be tighter and tending more towards levels similar to those seen in the 2003-2008 period.

Figure 11: IEA Medium-term oil market balance (Higher / Lower GDP Scenarios)





Source: IEA Medium Term oil market report, June 2009

Unconventional Oil

Longer term technical advances and economic pressures may raise the potential for economically exploiting alternative oil sources. These could include the large deposits of oil and tar sands in Alberta (Canada) and Venezuela. An alternative source is oil shale, with most of the confirmed deposits located in the USA (Colorado, Utah and Wyoming), although deposits are also thought to be spread across other parts of the globe. We note, however, that it is highly unlikely that UK refineries will be able to process non-conventional crudes.

There is also potential to source oil from coal- and gas-to-liquids plants as well as heavy oil, a particularly viscous form of crude. The largest reserves of heavy oil are located near the Orinoco River (Venezuela). Though often found at relatively shallow depths, difficulties surrounding extraction remain, and transportation is complex as the crude tends not to “flow”.

These sources may act as a counterbalance to the increasing geographic and organisational concentration of crude supply from OPEC in the Middle East. In the IEA’s Reference Scenario, that unconventional oil production volumes (excluding Venezuela) are expected to grow by 6.6% per annum between 2008 and 2030 (from 1.8mb/d to 7.4mb/d); more than 3 times the 2008 output of Iraq. However, high costs and environmental concerns in terms of the energy required to extract oil from these sources and the associated carbon dioxide emissions may limit future development of these sources. For example, it has been reported that Royal Dutch Shell shareholders are requesting a study by the oil company into oil sand operations in Canada, which are seen as expensive, energy consuming and a threat to local minorities.[5]

This shifting supply and demand environment may raise new challenges in acquiring crude. These changes may occur in the context of reaching a global peak oil state, or as emerging alternative supply sources begin to be fully exploited.

[5] “Shell Shareholders Request Study Of Oil Sand Ops In Canada” Dow Jones International News, 19 January 2010

Potential future supply constraints

There are a number of possible drivers of future supply constraints. In particular, the Peak Oil hypothesis holds that the world is running out of oil reserves and that capacity shortages will prevail in the future. There does not appear to be conclusive evidence on the validity of this claim. In particular, peak oil is not likely to be a significant factor before 2030. A more significant potential driver of future scarcity in the time frames we are examining is the decline in non-OPEC production. Many non-OPEC producers are thought to have experienced their peak already, with aggregate non-OPEC production expected to peak around 2010.

This means that a larger proportion of the world's productive capacity is now concentrated in OPEC countries, where outside investment may be limited and so the potential full development of reserves may also be limited. Some commentators have argued that expectations of a persistent future supply demand imbalance contributed to price rises in the run-up to July 2008, and led to greater market reactions to any actual or perceived disruptions in available supply.

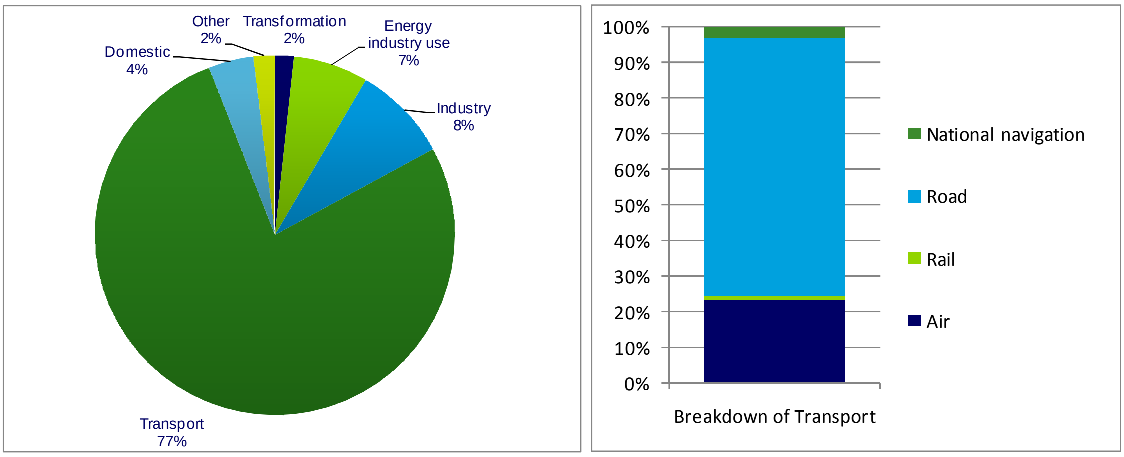
This heightened degree of scarcity of non-OPEC oil production is likely to further improve the economic rationale of unconventional reserve sources.

2.2 Refined products supply-demand

2.2.1 Structure of current UK demand by product/category of consumer

UK demand for petroleum products is mainly driven by demand from the transport sector, with road transport fuels accounting for over 70% of demand in 2008 and 23% from air transport fuels.

Figure 12: Petroleum product usage by main sector (2008)



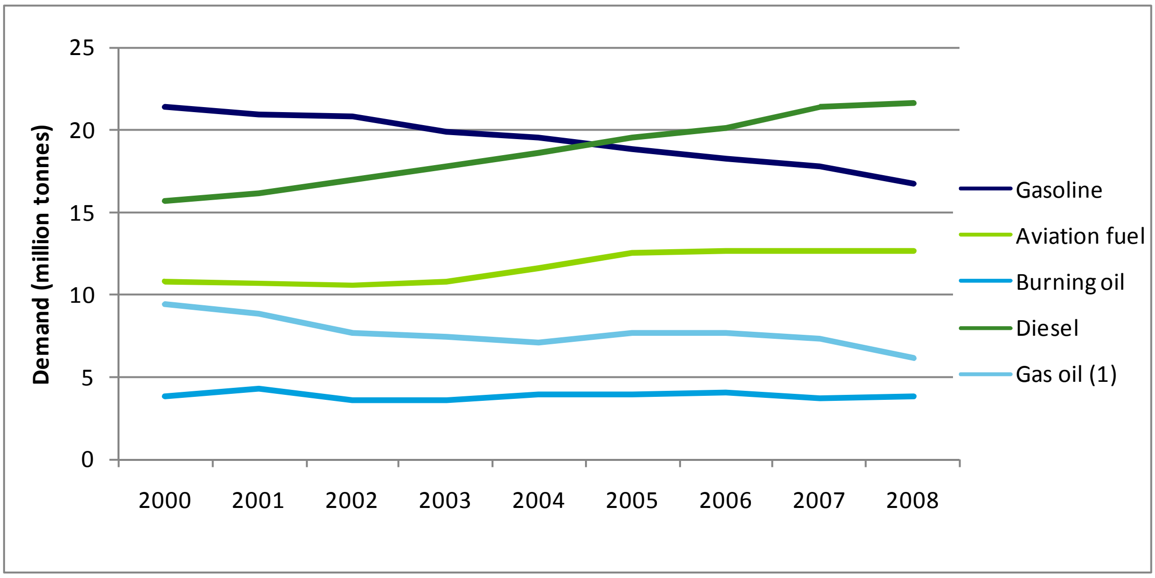
Source: DECC, Digest of UK Energy Statistics 2009, Table 3.2 (page 87)

Over the last decade, there has been an underlying change in the structure of the UK demand for petroleum products with a shift away from gasoline towards diesel products driven by a preference towards diesel engine vehicles. There has also been strong growth in UK-originated air travel, partly through growth of low cost airlines, which has increased the demand for aviation type fuels. This has mirrored the pattern of demand changes in Europe as a whole.

Figure 13 shows the change in UK demand for five types of petroleum products between 2000 and 2008. Where gasoline (motor spirit) demand has decreased by 22% and gas oil by 34% over the period, diesel demand has increased by over 38% and aviation fuel by over 17% in the same period.

Although demand patterns for diesel and gas oil differ considerably, we examine diesel/ gas oil as a single product grouping in the remainder of this report. This is because diesel and gas oil are not disaggregated in world trade statistics, as diesel is essentially a more refined form of gas oil. However, this aggregation is likely to mask different security of supply implications for diesel and gas oil, as the additional refining requirements for the production of diesel from gas oil means that the sources of supply of these two products are not interchangeable.

Figure 13: UK demand for petroleum products – 2000 to 2008



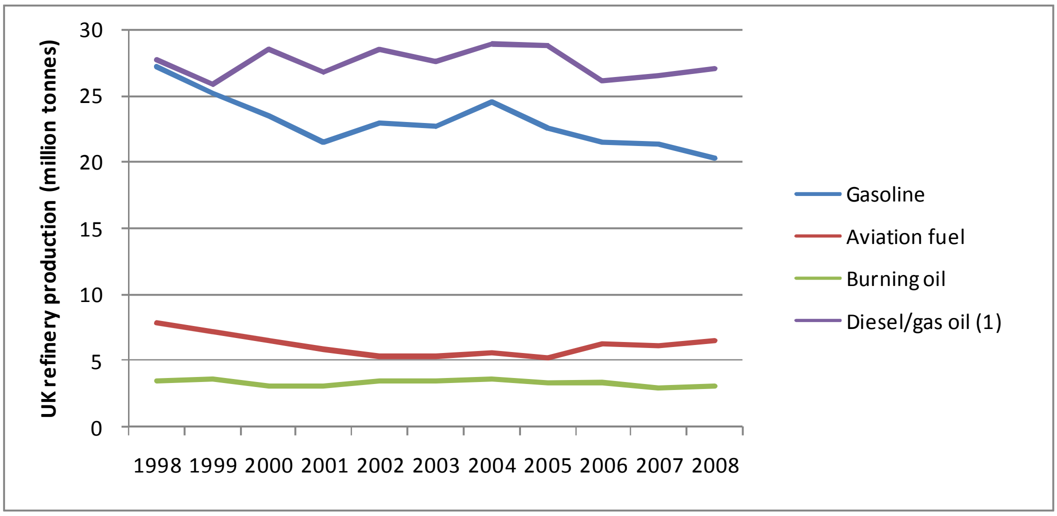
Source: DECC; Note (1) Includes marine diesel oil

2.2.2 UK refinery production

As described in section 1.1, the UK refining sector has undergone significant rationalisation in recent years. At the start of 2010, there were eight major refineries in operation in the UK with a total nameplate capacity of around 1.7mbd. There are also an additional three specialised refineries with minimal capacity.

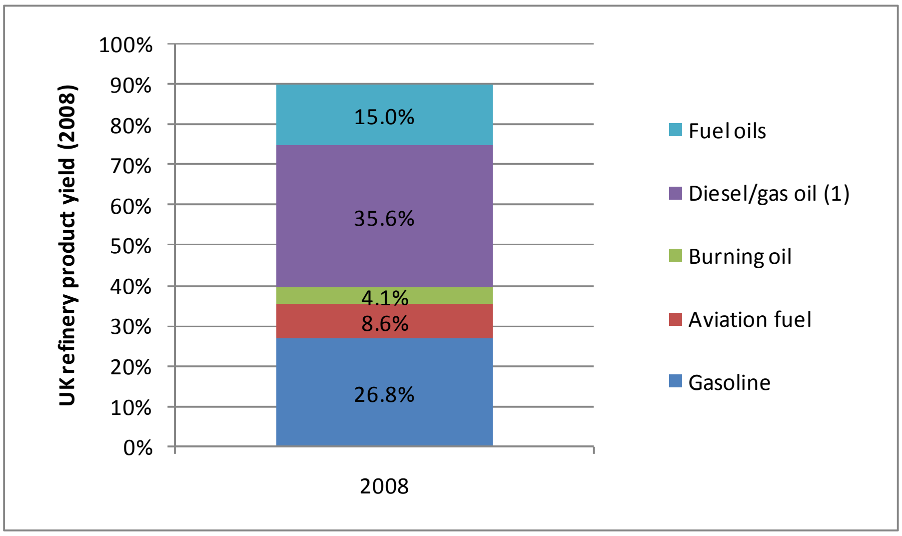
UK refineries were designed to produce gasoline for cars and fuel oil for power generation. As such, the UK has over-capacity for gasoline and is short on middle distillate capacity (diesel/gas oil and aviation fuel) with this position being extended by the shift in UK product demand. Refiners have responded to this change by enhancing product yields for diesel/gas oil and aviation fuel at the expense of gasoline. However, further yield changes are unlikely without significant investment in UK refineries.

Figure 14: UK refinery production – 1998 to 2008



Source: DUKES; Note (1) Includes marine diesel oil

Figure 15: Refinery production product yields – 2008



Source: DUKES; Note (1) Includes marine diesel oil

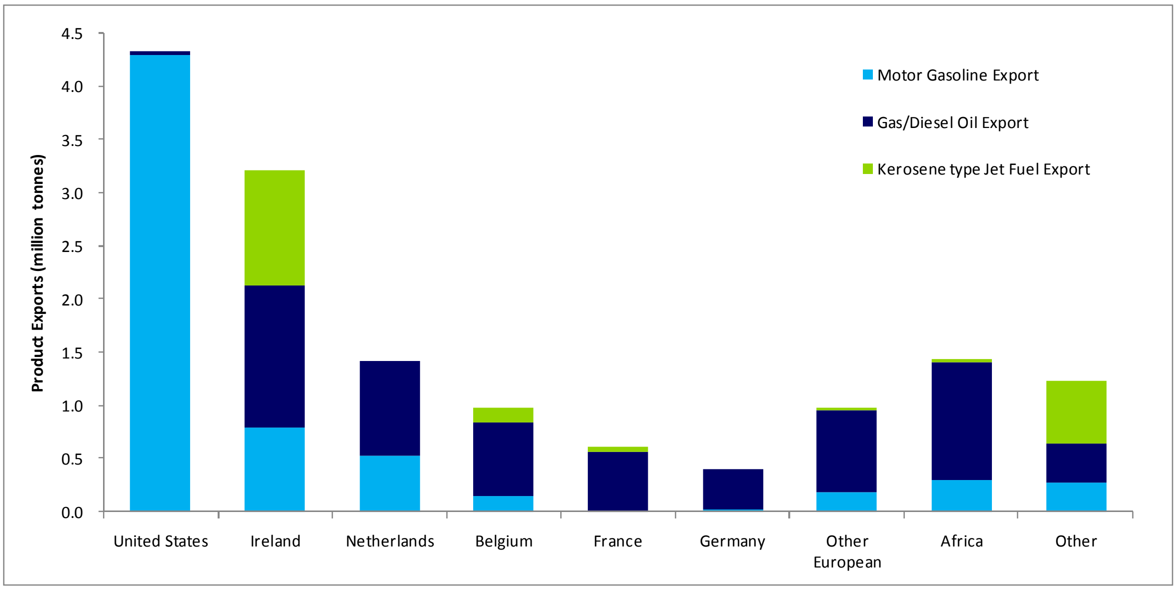
The current yields from UK refineries for 2008 are shown in Figure 15. These yields are achieved through the use of light sweet crude varieties mainly sourced from the North Sea. To maintain these yields in the future, UK refineries will need to source similar types of crude from other regions (such as West Africa or Caspian crude, where production volumes are increasing). The use of heavier crudes in UK refineries is likely to require desulphurisation of refinery intermediates before upgrading, additional desulphurisation of finished products and additional control equipment to maintain sulphur emissions within agreed limits. This is in general technically infeasible given restricted desulphurisation capacity or at a minimum would lead to much lower yields of gasoline and middle distillates and higher yields of fuel oil. As a result, for UK refineries to maintain the same level of output for transport fuels with sourer crude, new investment in refining processes would be needed. The cost of capacity changes to process sourer crudes are estimated at between £260m and £440m.[6]

2.2.3 Exports

The UK exports a number of petroleum products produced at UK refiners, with the 2008 exports shown in Figure 16. Excess gasoline production is mainly exported to the USA, with over 4mt exported in 2008. There are also some gasoline exports to a number of European countries. Given its proximity to the UK, Ireland received over 3mt of petroleum products from the UK, including mainly diesel/gas oil and aviation fuel, but also gasoline.

UK production of diesel/gas oil in 2008 was similar to the UK demand at around 27mt. However, the UK exported over 7mt and imported a similar amount in the same period. This may be driven purely by commercial reasons but it is possible that the exports are of lower grade diesel oil (for example to Africa) and of products that need further processing abroad. There may be some limitations in storage or processing capacity in the UK for further processing of gas oil. Information on the split of exports between diesel oil and gas oil is not available, so it is not clear whether some of these exports could be used in the UK without further processing.

Figure 16: UK export destinations by product (2008)



Source: IEA

2.2.4 Sources of imports

The main imports to the UK consist of middle distillate products such as diesel/gas oil and aviation fuel. The main source for diesel/gas oil is Europe and Russia, providing over 80% of all imports[7].

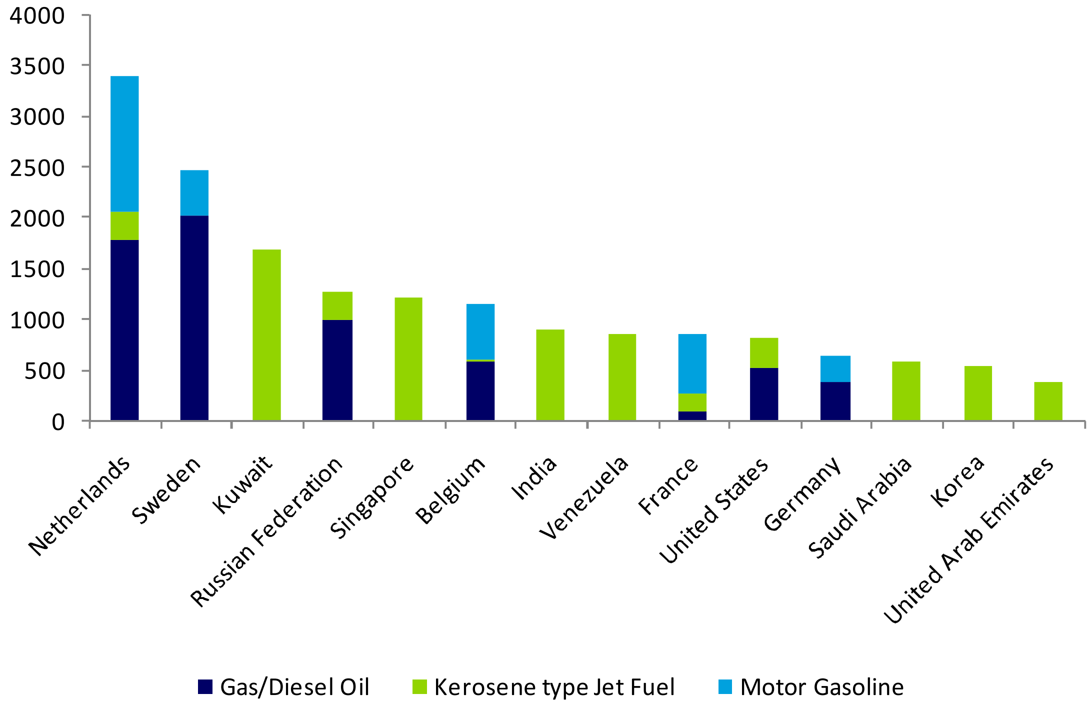
[6] Industry sources. Estimates based on a cost range of €300m to €500m.

[7] In general, Russian gas oil is processed into diesel by European refineries.

In 2008, Sweden and the Netherlands each accounted for 26% of UK imports, followed by Russia (12%), Belgium (7%) and Germany (5%). There were also imports from the USA and Canada of around 7%.

The main supply of aviation fuel to the UK originates from Asia (31% in 2008) and the Middle East (27%), with additional supplies from South America. Base on IEA data, the largest single sources of import in 2008 were Kuwait (18%), Singapore (14%), India and Venezuela (with 9% each).

Figure 17: Sources of UK Refined Product Imports (2008)



Source: IEA

2.2.5 Future refinery prospects

International refining prospects

The main investment in new refining capacity over the next five years is expected to be in Asia (primarily India) and the Middle East (primarily Saudi Arabia, Kuwait, Qatar and UAE). China accounts for 33% of the expected increase of 8.7mbd by 2014 according to the IEA[8], but the extent to which this new capacity will be export focused is uncertain. This follows recent refinery additions, such as the expansion of the Reliance Jamnagar in India facility with an additional 0.6mbd capacity being added.

[8] "Oil Market Report", IEA, December 2009

In parallel, the reduction in product demand seen in 2009 has led to a decrease in refinery throughput in Europe, the USA and Japan. This, together with growth in new capacity, has led to an increase in refinery overcapacity which is likely to remain over the next few years and depress refinery margins.

This may lead to some refineries being mothballed or decommissioned in the near future, with a number of companies currently evaluating their options. For example, Chevron announced on 20 January 2010 that it was cutting jobs in its refinery business in the USA and considering exiting some markets. Shell has a strategy to concentrate its refining footprint and has put its UK Stanlow refinery up for sale.

These, and other key trends in global refining are summarised in Box 1 below.

Box 1: Key trends in refining

Investment in new capacity

Growth in new capacity is expected to be dominated by China, other Asia – primarily India – and the Middle East.

- **China** has been building at an average of 450 – 500 kbd per year, with announced plans indicating a continuation of this trend. Capacity expansion is driven by expected future growth in demand for refined products, combined with China's declared policy of "self-sufficiency".

- Countries in the **Middle East** are predicted to account for 17% (1.5mbd) of the growth in new capacity by 2014. These refineries are largely export focussed, typically designed to meet the most stringent quality specifications in Western markets, and are aimed at export markets in Europe, the US and Asia. The complexity and scale of these refineries provide a competitive advantage in comparison with many domestic refiners in Europe and the US. The new capacity reflects a desire to diversify Middle Eastern economies away from dependence on crude oil production to higher value added services such as refined products.

- **India** accounts for much of the 2.1 mbd of new capacity expected from other Asian countries by 2014. These refineries are largely export-focused, and are designed to meet Western quality specifications. The capacity growth is supported by the Indian government, which has provided a seven-year tax break on new-build refineries. This reflects government objectives of developing an industrial base and supporting economic growth, as well as a need to meet expected future growth in demand for refined products as oil consumption per capita increases.

Acquisition of existing refineries

A further key trend is the acquisition of foreign refineries, primarily by Chinese oil companies.

Companies such as PetroChina have increased their downstream presence through a series of refinery acquisitions, mainly in Singapore, Japan and Malaysia. Analysts[9] have suggested that the recent acquisitions reflect trading tactics rather than a drive to secure further resources, given the number of new domestic refineries in the pipeline. The acquisition of downstream assets allows Chinese companies to gain better understanding of and possible influence over prices on world markets. This is because ownership of sources of fuel supply creates leverage to trade in the spot Singapore oil market, where small volumes of deals can have implications for contract prices. These acquisitions also allow Chinese firms to participate in European arbitrage opportunities.

Excess capacity and resulting low margins

The combinations of faltering demand growth due to the recession and the large increase in new refining capacity have led to low refining margins and increasing pressure on merchant refiners. The response of refiners to these pressures may include the following.

- **Refinery sales.** Several operators have announced their intention to sell refineries as part of an attempt to consolidate their portfolio to focus only on the best performing assets. It will be difficult to sell very uncompetitive refineries, but those with some source of competitive advantage may be attractive to purchases with a relatively long time horizon[10]. This could explain PetroChina's interest in Grangemouth.

- **Closure:** refineries which are currently obtaining negative margins are possible candidates for closure. However, in practice only a few refineries are likely to be closed, due to the high expense and the fact that each closure that does take place helps to support the rest of the market. Political context is also important, with some countries seeing a strategic advantage in maintaining a strong refining sector due to security of supply issues, or a desire to protect local employment[10]. Nevertheless, the IEA reports that capacity rationalisation has started in North and Latin America[11].

- **Delays:** projects involving capacity enhancements may be delayed or cancelled.

The outlook for refining capacity in the longer term depends on how quickly demand rebounds, how much investment is scaled back and how quickly investment rebounds. If global demand recovers slowly, then spare capacity could remain at current levels until the middle of this decade[12]. (IEA, WEO 2009)

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[9] See for example Reuters, May 25 2009, "PetroChina refinery bid reflects China price ambition". Available at < http://www.reuters.com/article/idUSTRE54O1I020090525>

[10] Winhal, B. December 2009, "Is refining going bust?" Energy Institute, Future Refining & Storage

[11] "Oil Market Report", IEA, December 2009

[12] IEA, World Energy Outlook, 2009

UK refining prospects

There are very few, if any, significant refinery projects expected at UK refineries by 2015 that will make a material change to the total refining capacity or achievable yield structures[13]. This reflects a number of factors of the UK refining sector.

- **Environmental investments largely completed**. Most UK refineries have already invested to meet the current most stringent EU specifications for transport fuels and so little further "mandated" investment is expected by 2015.

- **Existing refinery complexity**. Most UK refineries are already "complex" in configuration meaning that they have some form of major upgrading plant, typically converting vacuum gas oil ("**VGO**") into lighter distillate products. Many UK refineries invested in fluidised catalytic cracking ("**FCC**") units in earlier decades which favour gasoline production over that of middle distillates.

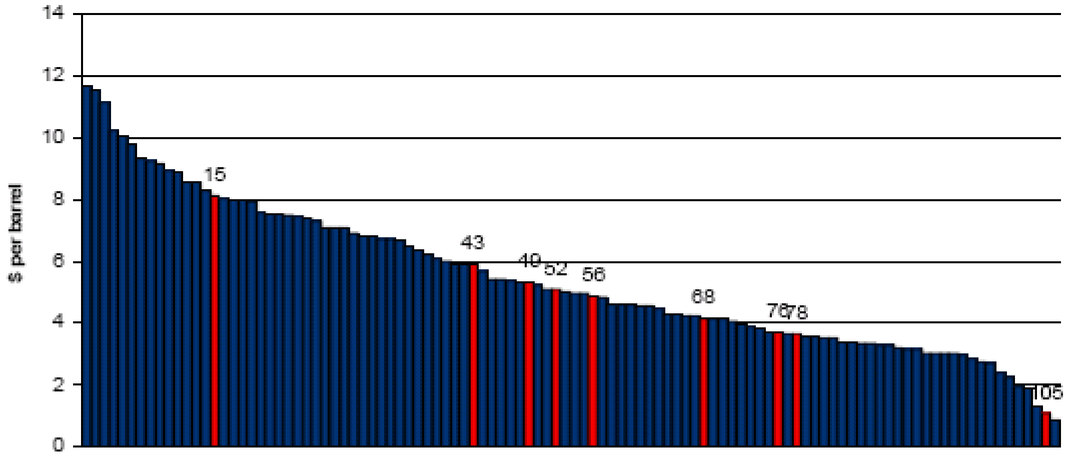
- **Cost of investing in conversion units**. A more ideal configuration for a UK refinery, given the demand profile in local markets, is one where the major upgrading plant is a VGO hydrocracker unit (**"HCU"**) which produces relatively higher volumes of middle distillate rather than gasoline. However these plants are expensive to construct and rarely are economically justifiable in Europe where other conversion plants already exist (such as FCC units).[14]

- **Limited growth in the market**. North West Europe is a relatively mature market, with overall oil product demand growth likely to be limited, although changes in product mix towards middle distillates are expected to continue. Decreasing utilisation rates given the current position of excess capacity, together with low margins at UK refineries (Figure 18), means that it will be difficult for many new projects to realise an acceptable return on investment in the UK.

[13] The Total Lindsey HDS3 project, which is scheduled to come on stream in 2010, is the only known project which will change the yield profile for UK refineries. Approximately 1mt p.a of gas oil will be processed into a similar quantity of 10ppm diesel base blend. The project will also provide increased capability for processing higher sulphur crude types.

[14] Where a refinery has no conversion capacity, there may be an economic case for installing a conversion plant such as an HCU or FCCU. The Petroplus refinery at Teesside, currently shutdown, has no such conversion capacity. However, its relatively small scale (100kbd or about 5mt p.a.) and likely high capital costs of an HCU means that it is extremely unlikely that a credible investment case can be made for such a major investment.

Figure 18: Margins for EU refineries – UK refineries shown in red



Source: The Competitive Context of the European Petroleum Refining Industry in Light of the EU ETS, NERA paper for EUROPIA, October 2007

There may be smaller projects and investments that may progress but they will not materially change refinery capacity or yields, for example utility projects (steam and power) and those improving safety and reliability.

2.3 UK balance tables: 2008 - 2015 - 2030

To undertake the analysis of supply interruptions, we have developed a number of scenarios for the future UK supply and demand balance for crude oil and petroleum products. This has been developed in the following stages:

- defining a base and low scenario for the UK's refining capacity;
- calculating crude oil requirements, based on UK refining capacity scenarios, including the potential sources of crude given the decline in UK and Norwegian oil production;
- estimating implied UK production of petroleum products, with the work focusing on gasoline, diesel/gas oil and aviation fuel, and to a lesser extent burning oil; and
- calculating the supply-demand position for the UK, based on DECC base and high demand cases, and assessing the additional net import requirements above 2008 levels.

Refining capacity

For the purpose of assessing the impact on downstream oil resilience of increased import dependency, we have developed a base and low UK refinery capacity scenario. The 'base refining' scenario takes the existing capacity of the eight major UK refineries at the start of 2010, with a nameplate capacity of around 1.7mbd. The 'low refining' scenario assumes a 27% reduction in this capacity (equivalent to around 1.24mbd) by assuming that two refineries shut down before 2015. There are a number of commercial factors that could lead to a decision to close refineries including the following.

- Low capacity/lack of scale of operations leading to relatively high operating costs per unit of throughput, with some UK refineries having low margins relative to other European refineries.

- Low complexity or poor alignment of product slates with local market requirements. This would lead to higher levels of product exports and lower "net-back" prices for product sales and lower levels of production of the higher value distillate products compared to lower value products such as fuel oil.

- Low utilisation rates and/or recent periods of non-maintenance related shutdown suggesting low refining margins/profitability.

- Higher returns on capital elsewhere, either to another sector or another region. Companies will try to off-load a refinery through a sale, but a buyer not being found, could lead to the closure of the refinery.

Crude oil requirements

Based on the two refining capacity scenarios, the UK requirement for crude oil is shown in Table 2 below. It assumes that UK refineries will continue to source light sweet varieties of crude in the future to minimise investment and maximise transport product yields to meet demand. As a simplifying assumption, the utilisation rate assumed in both scenarios is the same as that seen in 2008. This enables a greater distinction between the two scenarios in terms of import dependency. In reality, a scenario with lower refining capacity is likely to have higher utilisation rates compared to one with higher refining capacity.

We have used DECC's UKCS decline assumptions of 4.5% decrease in production per annum from 2008 values through to 2030. For Norway and other European sources, we have assumed a decline of around 3% over the period. The gap in crude supply from declining North Sea oil is filled by crude imports from the growing new production capacity sources of light, sweet crude, in particular from North (Algeria and Libya) and West African (Nigeria and Angola) countries, as well as imports from the Caspian region (Kazakhstan).

Table 2: Crude demand under two refining scenarios

		Base refining scenario			Low refining scenario		
Year	Units	2008	2015	2030	2008	2015	2030
Refining capacity	mbd	-	1.70	1.70	-	1.24	1.24
Assumed utilisation	%	81.5%	81.5%	81.5%	81.5%	81.5%	81.5%
Crude demand	m tonnes	75.7	72.1	72.1	75.7	52.8	52.8
Reduction in crude supply							
UK production	m tonnes	-	-6.7	-15.4	-	-6.7	-15.4
Norway	m tonnes	-	-6.9	-15.1	-	-6.9	-15.1
Other European	m tonnes	-	-0.3	-0.8	-	-0.3	-0.8
Increase in crude supply							
N. & W Africa	m tonnes	-	4.1	11.1	-	0.0	3.4
Caspian	m tonnes	-	6.2	16.6	-	0.0	5.0
Crude supply	m tonnes	-	72.1	72.1	-	61.8	52.8

Source: Deloitte analysis; IEA

Note: Increase in crude imports is calculated on the basis of the gap between UK demand and North Sea supply, and then allocated to the key suppliers of light sweet crude on the assumption that 60% of new demand is sourced from the Caspian (primarily Kazakhstan) and 40% from North and West Africa. This is informed by the relative capacity growth in these countries.

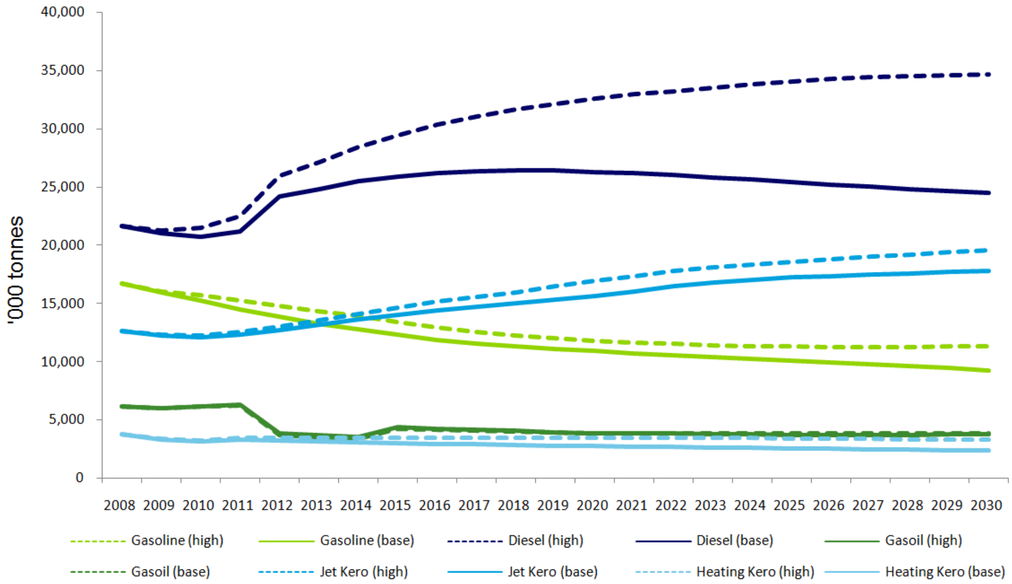
Excess crude supply in 2015 under 'low refining' scenario implies that the decline in UK crude demand is greater than the decline in UK/Norwegian crude production.

Oil product requirements

Using assumptions made on UK refining capacity and assumed utilisation, the implied UK production of oil products for 2015 and 2030 can be calculated. While it is possible that product yields may change from their current level to favour middle distillates in the future, this is likely to require further investment in processing capacity at UK refineries. Given uncertainties as to whether and when these changes may occur, the product yields used for the scenarios are the same as those for 2008, as shown previously in Figure 15.

To assess the supply demand position for each product, DECC's projections for UK oil products up to 2030 have been used. Figure 19 shows the demand profile assumed in DECC's Base case projections and High case projections.

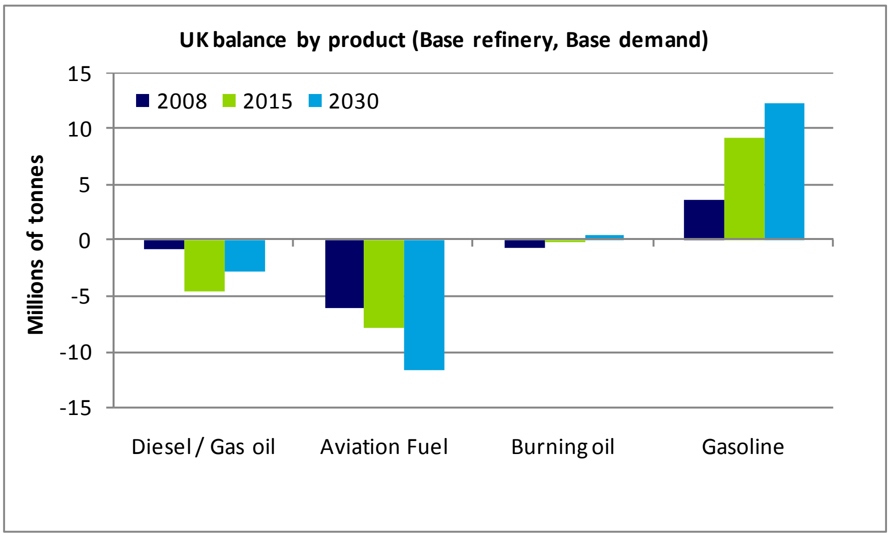
Figure 19: UK 'Base' and 'High' projections for UK product demand, 2008-2030



Source: DECC

Using the implied production of UK oil products based on the two refinery scenarios and DECC's demand projections, a supply-demand balance by product can be calculated. This is shown in Figure 20 for the base refinery and base demand scenario. It shows that the UK would need to increase diesel imports by 3.8mt by 2015 (a 50% increase on 2008 imports), but a lower increase of 2.0mt in 2030. This lower demand for diesel will result from greater fuel efficiencies as well as a move towards alternative fuels for the transport sector such as electric cars.

Figure 20: UK product balance – Base refinery and base demand



Source: Deloitte analysis

In all scenarios used in this analysis, the UK would still have sufficient gasoline production capacity to meet projected future demand, and additional imports of burning oil in 2015 would only be required in a low refining scenario (up to 0.7mt in 2015 in a high demand scenario).

Table 3 summarises the additional imports required for these two products under the high and low refinery scenarios and DECC's two alternative demand scenarios. It shows that increases in import demand are forecast under all scenarios, even with base case demand and maintained refining capacity. Under base case demand, gas/diesel oil imports do however reduce between 2015 and 2030 as described above. Very considerable increases are projected under high case demand assumptions, with aviation fuel imports almost doubling and gas/diesel oil imports more than doubling by 2030 with base refining capacity. These increases are even more extreme under the assumption of reduced refining capacity.

Table 3: Additional product import requirements over 2008 under two refining scenarios

Millions of tonnes	Current imports 2008	Additional oil product imports			
		Base refinery		Low refinery	
		2015	2030	2015	2030
Base case demand					
Gas/Diesel oil	7.6	3.8	2.0	10.7	8.8
% increase on 2008 imports		*50%*	*26%*	*140%*	*116%*
Aviation Fuel	8.2	1.9	5.6	3.5	7.3
% increase on 2008 imports		*23%*	*69%*	*43%*	*89%*
High case demand					
Gas/Diesel oil	7.6	7.5	12.0	14.3	18.9
% increase on 2008 imports		*98%*	*157%*	*187%*	*247%*
Aviation Fuel	8.2	2.4	7.3	4.1	9.0
% increase on 2008 imports		*30%*	*90%*	*50%*	*110%*

Source: Deloitte analysis
Note: UK domestic production assumes the same relative product yields as in 2008.
Current imports are greater than the demand-supply gap shown in Figure 20. This is due to factors such different product specifications being included in the same product category and trading for arbitrage reasons.

3 The UK's oil supply chain

This section provides information on the UK's oil supply chain, both for crude and for oil products. It sets out the key components of the supply chain identifying the time-lags and quantities in transit through each of the key supply routes. It also discusses the primary and secondary distribution channels to the final consumer. This information is then used to overlay the supply interruption scenarios and support the analysis on potential mitigating options in each case.

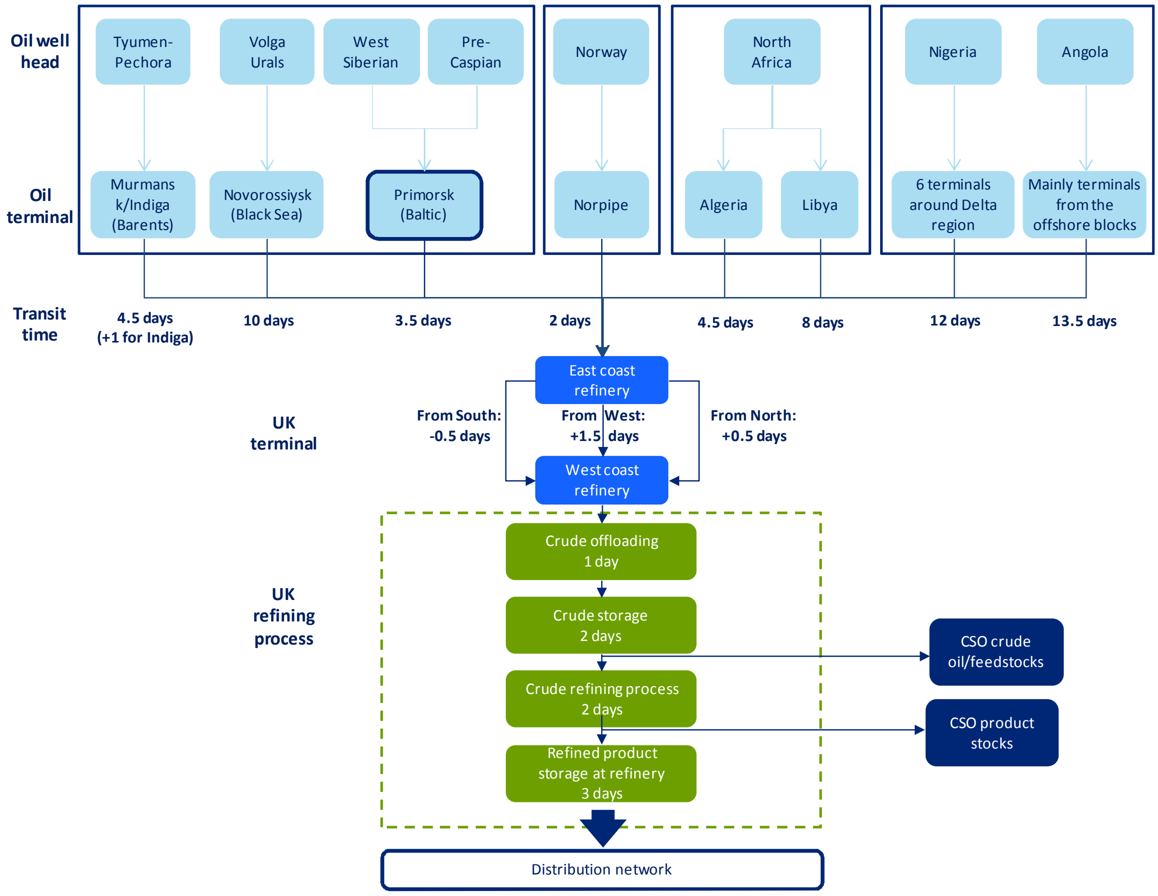
3.1 Crude supply chain

3.1.1 Overview description of mapping from well-head to output from UK refinery

Figure 21 outlines the supply chain from oil well-head to product output at UK refineries for the main countries from which the UK imports its crude[15]. The majority of crude is imported by sea, with the minimum transit time shown in the figure below. The two key crude oil pipelines into the UK are Norpipe which carries crude from a number of UK and Norwegian fields to the Teesside processing and export facility, and the Forties pipeline which carries crude from UK and Norwegian to processing facilities at BP Kinneil, Grangemouth. The majority of Norwegian crude imports are transported via pipeline given the cost advantages, but some imports from Norwegian fields are also transported by ship.

[15] There are also other suppliers of crude oil to the UK. These include Middle Eastern suppliers, who supplied around 1% of crude imports in 2008, and new suppliers such as Kazakhstan, who will tend to supply through Black Sea ports.

Figure 21: Crude oil imports and UK refinery supply chain



3.1.2 Identification of time-lag and quantities in transit/processing/storage through supply chain

The transit time to the UK market depends on the origin of the crude oil, the route taken by the ship and the average speed of travel. The travel times included in Figure 21 represent the minimum possible time required to travel to the UK. This is likely to be the case at the time of a disruption where ships can average 15 knots to minimise journey times.

The destination of the crude also has an impact on the total travel time, as ships originating north of the UK will typically take half a day longer to reach a refinery on the west coast of the UK compared to those refineries in the east. Similarly, crude shipments from Africa can take half a day less to arrive at refineries in the south and west, compared to those on the north east coast of the UK.

At any one point in time, there is a certain volume of crude heading for the UK by ship. This depends on the distance travelled from source, the size of the ship and the total volume imported in a given year. These key parameters can be used to calculate the number of crude deliveries by ship per year for each source, as shown in Table 4. For example, in the case of Russian crude being imported from Primorsk, the average size of ship is around 100,000 tonnes. Given the level of imports from Russia, this implies 66 deliveries in 2008, which equates to a delivery every five to six days. On average, there could be four to six ships loaded with crude heading for the UK at any point in time, with a total of around 0.5mt of crude.

Table 4: Sources of crude imports and volume of crude

Import source	Transit (days)	Ship size (m tonnes)	Volume (Base refining) 2008	2015	2030	Frequency (ships per year) 2008	2015	2030
Norway	2	0.080	30.1	23.2	15.1	75	58	38
Russia	4	0.100	6.6	6.6	6.6	66	66	66
North Africa	4-8	0.080	4.6	6.6	10.1	57	83	126
West Africa	12-14	0.135	4.6	6.6	10.1	34	49	75
Caspian	12-15	0.080	0.0	6.2	16.6	0	78	208

Source: Deloitte analysis; Note: Norway assumes that 20% of imports are by sea, 80% by pipeline. We have assumed that Russian imports remain constant over time, as the level of imports is currently small and the pipeline link to China and Kozmino Bay currently under construction indicates that new capacity is more likely to be diverted eastwards.

Once the ship arrives in the UK, the crude will need to be offloaded which takes at least one day and on average two, but could be longer, for example in poor weather conditions. Once the crude is offloaded, it will need to be stored for at least two days before it can be processed through the refinery to allow for settlement of the crude. The refining process can be undertaken in a relatively short period of time, but given that there are a number of processes that need to be undertaken, partly refined products are often held in storage before the entire refining process is completed. Therefore, we have assumed that it normally takes around two days for the crude to be processed into a whole set of oil products. These products are often stored for up to three days at the refinery for testing before entering the distribution network and sold to wholesalers or final consumers.

3.2 Refined product supply chain

3.2.1 Overview description of mapping from export refinery to UK terminals

The starting point for considering the supply chain of imported refined products is the exit of the overseas refinery. In many cases, the products need to be transported by pipeline to a port where they can be loaded on to a ship. Many refineries are located close to the coast and therefore this transit time can be less than a day, while others may have loading facilities adjacent to the site. It will typically take around two days to load a shipment, although this can be delayed by poor weather conditions, such as freezing temperatures or high winds, which may delay departure of a ship. Typically, ships carrying products are smaller than those carrying crude oil, with short distances being covered by ships up to 30,000 tonnes. Longer routes, such as the Middle East and Asia will have larger ships of up to 70,000 tonnes.

Section 2.2.4 described the main sources of oil product imports to the UK. In the case of diesel / gas oil, the majority of imports are currently from Western Europe and from Russia. Typical transit times (without loading or unloading) from Rotterdam can be as low as a day for a destination in the Thames estuary, but could be up to two days for import terminals in the north or west coast of the UK. Transit times from Russia are similar to those of imported crude products of around four days from Baltic ports. For aviation fuel, transit times vary between 18 days from Kuwait, via the Suez Canal, up to 33 days from Asian refineries in Singapore and India via the Cape of Good Hope.

Time taken to travel to the final destination can also include booking time in addition to loading and transit time.

Products imported into the UK are offloaded at UK refineries as well as various import terminals located throughout the UK. For example, shipments from Rotterdam are unloaded at many UK locations, in particular at various terminals in the Thames estuary, and are transported further via pipeline into the UK's primary and secondary oil distribution system which is described in more detail in Section 3.3. The process of off-loading refined products from a ship will typically take two days.

Independent sea-fed terminals are typically smaller when compared to the import capabilities of UK refineries site in terms of storage capacity, the number of vessels and the maximum tonnage accepted. For example, Table 5 shows a comparison between NuStar's Grays Terminal (one of the largest independent terminals in the UK) with nearby Coryton refinery, which is the second smallest refinery in the UK and is thought to be most constrained in terms of import capacity[16]. Around two-thirds of product imports come through import facilities at UK refineries, with the remainder entering the UK through dedicated import terminals.

Table 5: Key metrics of an import terminal and import capacity at a UK refinery

	Coryton	Grays
Storage Capacity (barrels)	4,000,000	2,000,000
Jetties	5	2
Maximum ship size (dwt)	300,000	40,000

Source: UKPIA and Tank Storage Association; Note: dwt = dead weight tonnage

As discussed in Section 2.3, in the 'low refining' scenario, we have assumed that the refineries that are shut-down would continue to operate as import/storage terminals. The main driver for this is access to existing infrastructure, such as jetties, storage tanks, pipelines and links to the downstream network, to supply existing market supply. This will ensure continued supply of oil products to that particular region even if the refinery is no longer in use. This approach is indeed what has happened at the Teesside refinery, where the import facilities continue to operate following the shut-down of the refinery[17].

[16] An average comparison across UK terminals and refineries would be even more stark

[17] The majority of UK refineries decommissioned in the last 30 years have not been converted into major import terminals, but have been developed for alternative uses such as LNG import facilities. However, for the purpose of our analysis we assume that closed refineries would be converted into import terminals.

3.2.2 Identification of time-lag and quantities in transit/storage through supply chain

At any one point in time, there is a certain volume of refined product imports heading for the UK by ship. This will depend on the distance travelled from source, the size of the ship and the total volume imported in a given year. These key parameters can be used to calculate the number of refined product deliveries by ship per year for each source, as shown in Table 4, which focuses on the two main product imports – diesel / gas oil and aviation fuel.

Table 6: Sources of refined product imports and volumes

	Transit(*)	Ship size	Volume (Base refining)			Frequency (ships per year)		
Import source	(days)	(m tonnes)	2008	2015	2030	2008	2015	2030
Diesel/gas oil								
Europe	2-3	0.03	5.5	5.5	5.5	183	183	183
Russia	4	0.04	0.9	2.4	1.7	22	60	42
Middle East	20	0.07	0.1	0.9	0.5	2	13	8
N. & S. America	12	0.05	0.5	1.3	0.9	10	26	18
Asia	30	0.07	0.0	0.8	0.4	0	11	6
Aviation Fuel								
Europe	2-3	0.03	0.6	0.6	0.6	19	19	19
Russia	4	0.04	0.1	0.1	0.1	4	4	4
Middle East	20	0.07	2.2	3.1	4.8	32	44	68
N. & S. America	12	0.05	1.0	1.2	1.6	20	24	32
Asia	30	0.07	2.5	3.3	5.0	36	48	72

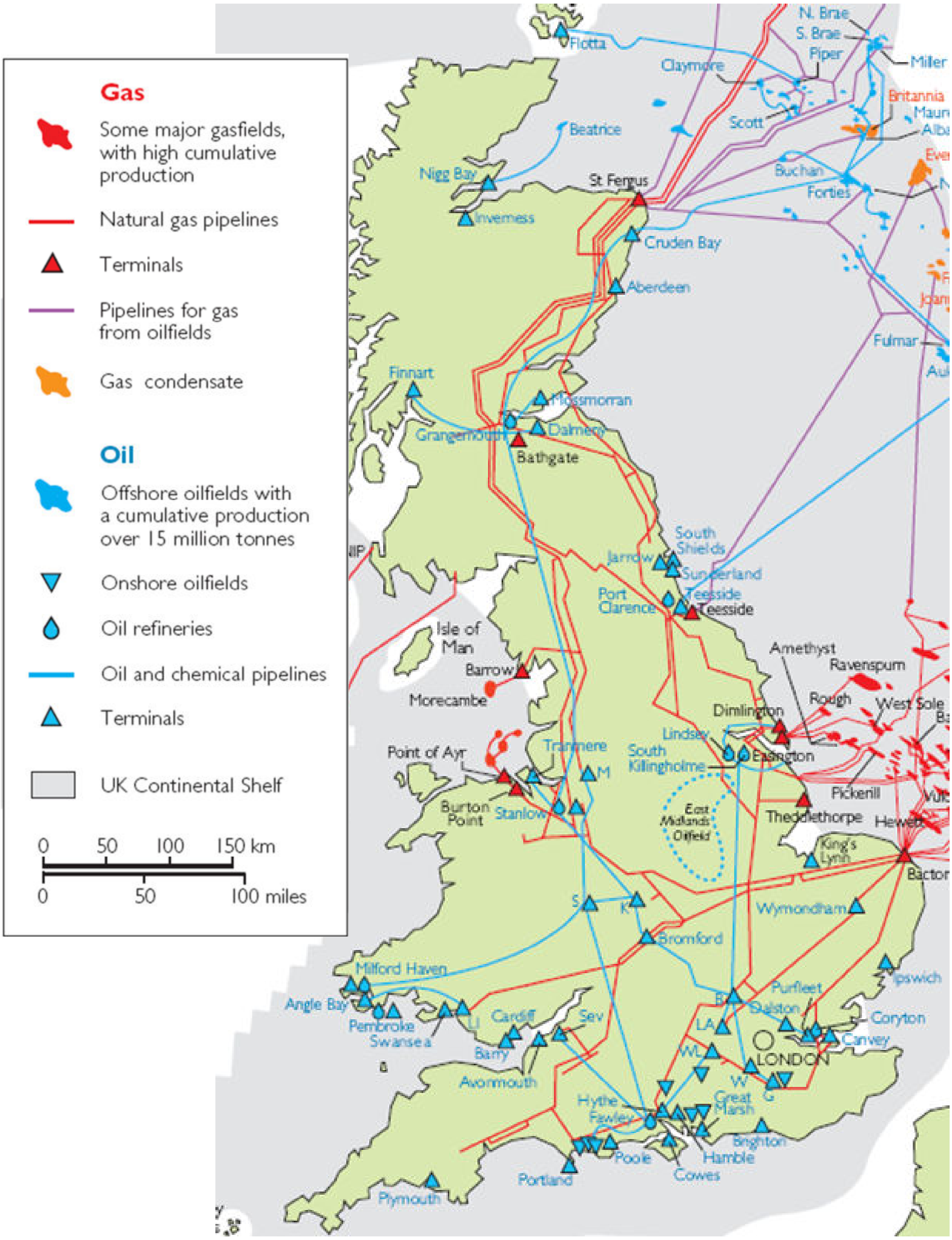
Source: Deloitte analysis;
Note: additional imports for diesel/gas oil assumed to be sourced 40% from Russia, 20% each from Middle East, North America and Asia; additional aviation fuel imports assumed to be 45% each from Middle East and Asia, and 5% each from Venezuela and North America. This is on the basis of current supply and future trends in capacity growth. Little change in supply volume has been assumed for Europe and Russia (except for Russian Diesel/Gas oil) due to the absence of major capacity expansion plans.
** Transit time excludes loading and unloading time*

3.3 UK distribution channels

Refineries and import terminals

The UK has a geographically dispersed infrastructure of entry points, primarily because of its island nature. It consists of eight operational coastal refineries, with associated import terminals able to accept refined product through dedicated berths and jetties. It is also well endowed with more than 16 independently owned and operated coastal product import and storage terminals. Together, these provide the apparatus to deliver the refined product to the primary distribution system.

Figure 22: UK downstream oil infrastructure map



Source: ONS

Primary and secondary distribution

The primary distribution system is the network of pipelines, sea (coastal tanker) and rail-fed terminals supplied by the refineries and key import terminals. Secondary distribution is almost all via road. There are a number of smaller storage depots which are supplied by large road tankers, with onward distribution by smaller units.

Transit methods vary geographically, by product and by end user type. As a broad summary, the South East, London and Midlands are primarily serviced by an array of trunk pipelines, whereas large volumes of product are moved by truck in Scotland, Wales, the North and South West. The South West also receives substantial volumes via coastal routes from the Welsh refineries and non-trivial quantities are also moved via coaster in Scotland. The last leg of distribution, to the retail/end user, is generally done by road throughout the UK. There are exceptions to this. Large-scale industrial centres, power stations and airports often have direct pipeline feeds into onsite storage and petro-chemical plants are often located on-site with refineries.

In the remainder of this section, we briefly highlight some of the supply interruption risks associated with the primary and secondary distribution system. However, this report focuses on the differential security of supply implications of product imports versus domestic refining capacity. A disruption to most aspects of the secondary distribution system would have the same impact whether the product being distributed had originated from a refinery or from product imports. We therefore do not consider disruption risks relating to the secondary distribution system beyond the brief discussion in this section.

Pipelines

The UK pipelines are a defined resource and already operating at near capacity. The pipelines can and have been used flexibly during previous disruptions to deliver product if there is an interruption, as in the case of the Buncefield fire where a number of pipelines were effectively closed. However, this can result in sub-optimal use of the distribution network and can lead to higher distribution costs and supply constraints. The supply of fuel to the London airports is an identified supply pinch point which may be partly alleviated by the increasing the capacity of existing or building new pipelines to Heathrow and Stansted.

Distribution centres

Product distribution depots are vulnerable to accidents, which do occur from time to time (for example, the Buncefield incident). The knock on effect of the loss of a large distribution centre or storage depot – for example the West London Depot – would have immediate local impacts and cause tightness or loss of supply. As the industry attempts to resolve the issue using nearby assets, a higher burden would be placed on regional assets and result in supply tightness across a wider area. Similarly, the impact of a fire at a road or rail gantry may result in a localised tightness of supply. Drivers may not be authorised to refuel tankers at other gantries and refuelling schedules are normally at capacity. For example, the loss of the Coryton road tanker gantry would have immediate impacts on East London and East Anglia.

Road

There are a defined number of road tankers and tanker drivers. There is little spare capacity in the tanker fleet and a generic failure in this area would have an immediate impact on the supply of refined products. As road transport is widely used as the final leg of distribution, any such disruption at this point would create challenges for mitigation. At this stage in the distribution process product is broadly dispersed and so too is the delivery infrastructure, and so flexibility to mitigate is vastly decreased. The disruption effects would be highly localised. It is highly improbable that the UK tanker fleet would be simultaneously impacted except in exceptional circumstances. Possible circumstances might be:

- industrial action by tanker drivers;
- prolonged severe weather event where roads become impassable for tankers (this is more likely to be a localised problem); and
- regulatory changes requiring the tanker fleet to be modified or as part of the carbon agenda requiring either tankers to be upgraded or replaced in part by rail transport.

Storage by UK consumer

Distributors generally know in advance the fuel demands of their businesses and store appropriate levels of fuel either on site or in flexible bunkering. They tend to react quickly to increase stock levels when there are supply concerns which can place significant strain on the distribution network. For their part, consumers now depend on the high availability and easy access to fuel. This has resulted in consumer behaviour such as fuel tanks in private cars being on average one third full[18]. This can create a demand spike when fuel is perceived to be in short supply as road users fill tanks to avoid running out.

[18] This figure was suggested by industry sources as a planning assumption during a 2006 DTI fuel shortage war-game exercise.

4 Key security of supply risks and scenarios

In this section, we define a number of interruption scenarios which highlight key security of supply risks. We outline our analytical framework for assessing the nature and impact of a range of supply interruptions, and present a selection of interruption scenarios which will be the focus of more detailed analysis. There may of course be other more extreme scenarios or scenarios with different effects that we have not considered.

4.1 Overview of analytical framework

The realised impact of a supply interruption can be assessed in a number of steps, which we set out in Figure 23 below. These include the following.

- **Defining the initial interruption scenario.** This involves defining the event which causes the initial disruption to supply, including specifying the product and volume which is disrupted, the duration of disruption, and the likelihood of the event occurring. This step also involves an assessment of the first-round impact on the UK, in terms of volumes disrupted and time to impact.

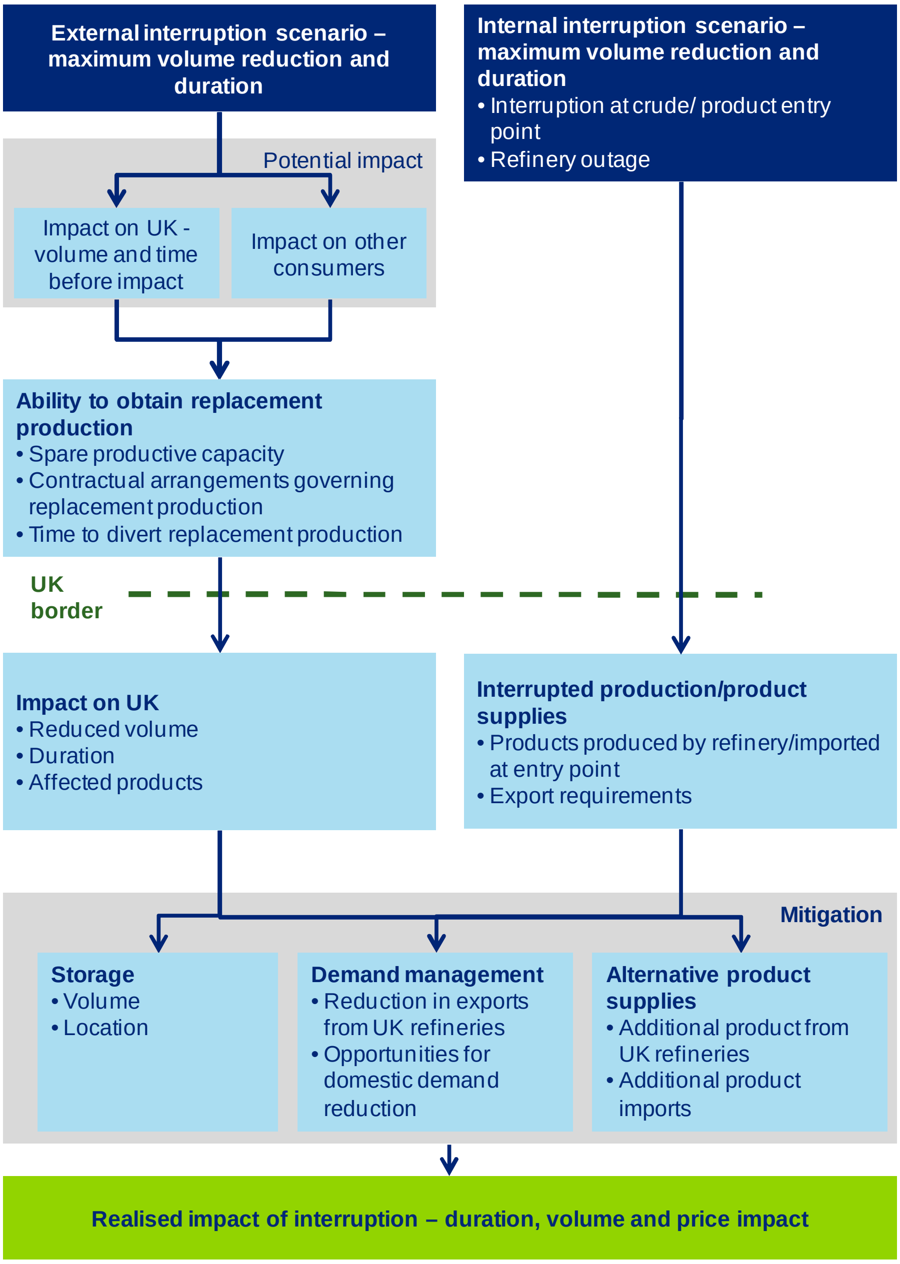
- **Considering measures to obtain replacement production.** The external interruption can be potentially offset by sourcing replacement crude or product imports. This will depend on the levels of spare capacity in the market, and the extent to which price increases following the interruption will incentivise additional production. This step requires the assessment of the timescales for sourcing the alternative production.

- **Second-round impact on the UK.** There may be market rigidities which mean that sufficient replacement production cannot be sourced. This step involves the assessment of the remaining physical disruption.

- **Assessing internal mitigating measures.** There are a number of additional mitigating measures which can help to offset an interruption. These include the use of stocks, demand management, and increased domestic production.

- **Assessing the realised impact of the interruption.** This step involves the assessment of final duration, volume and price impacts once all mitigating measures have been exhausted.

Figure 23: Framework for assessing impact of interruption scenarios



Source: Deloitte

Categories of interruption

The range of potential disruptions to supply is wide and the consequences are varied. As a preliminary step to defining a short-list of representative interruption scenarios to analyse in further detail, we have considered the potential causes of supply interruption. These can be grouped into the following broad categories.

- **Geopolitical interruptions.** These include a deliberate interruption to supplies for political reasons, or a sustained conflict in a source region. Source regions seen as more vulnerable to geopolitical tensions include the Middle East – a source of both crude and increasingly refined product supply – and some parts of West Africa.

- **Industrial action.** Industrial action may interrupt internal distribution – for example a road tanker driver strike – or cause supply interruption further upstream, for example industrial action at a refinery or at a port importing product.
- **Technical malfunctions**. These include infrastructure failure or accidents such as the explosion and subsequent fire at the Buncefield storage depot.
- **Financial failure.** Financial failure of supply counterparties or market institutions may lead to supply interruptions, although the impact is likely to be limited.
- **Terrorist attack.** Terrorism – such as an attack on a refinery, terminal, transit route or major distribution pipeline – has the potential to disrupt supply at a number of points on the supply chain, both in source regions and in the UK.

Supply interruptions may have a direct effect on the UK if the interruption involves a direct supplier to the UK. However, second round effects may also cause significant disruption to UK supplies. For example, an interruption in a crude-producing country which does not supply the UK may impact the UK through the interruption in crude supply to a refiner supplying the UK with refined products. Similarly, increased competition for UK sources of supply through supply interruptions in other parts of the world may impact the UK. For this reason, our representative scenarios include disruption to producers which do not directly supply the UK.

Description of price analysis methodology

A key aspect of the assessment of the impact of an interruption is the analysis of price effects resulting from the interruption. In this section, we describe our approach to assessing price changes following a supply disruption.

Given the large and liquid market for crude and petroleum products, it should be expected that a price response will occur in the event of a disruption and the market will reach a new equilibrium in prices and quantities. This response will be determined by the size of the supply interruption and the slopes of the world supply and demand curves. This methodology is represented in Figure 24.

We consider the short run impact of an interruption and the price response in the spot commodities market. We take elasticity estimates from previous studies to determine the slope of the demand curve for the various products and we assume that supply is inelastic in both crude and product markets, given the short-run price impact under consideration.

From the initial equilibrium point e_w a supply shock of size Δq shifts the level of world supply from Qw to Qw'. Prices will be under upward pressure as the product is now relatively scarce. The degree to which prices increase, Δp, is determined by the slope of the demand curve. This is the price elasticity of demand. The more inelastic the demand, the less demand will respond to a price increase and so a greater price shock is required to ration demand.

The change in price, Δp, reflects the immediate price impact following an interruption of size Δq. The speed at which prices revert to their pre-interruption level will depend on market conditions, such as the level of spare capacity. The initial price increase may therefore apply for only a very short space of time, before alternative supply sources are able to flow through to the market.

We note that this approach to estimating price impacts is stylised, and assumes that elasticity values are equally applicable in different market contexts. However, in practice elasticity values may vary depending on market conditions. For example, little or no price response may be needed if markets are satisfied that the interruption is temporary and that there are ample levels of spare capacity in the market, as consumers will simply run down their stocks in the interim period.

Table 7 below sets out our assumptions around elasticity estimates.

Figure 24: Negative Supply Shock - Demand and Inelastic Supply

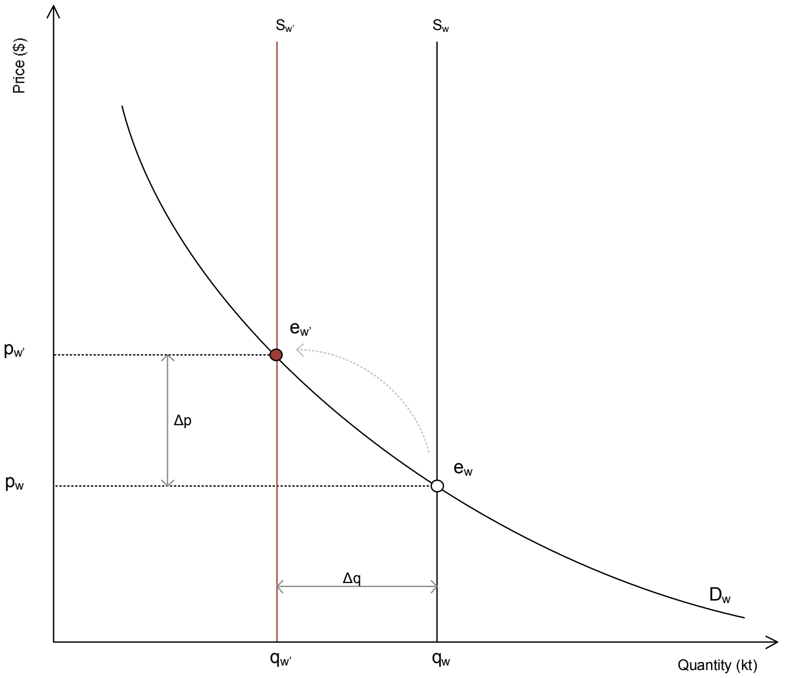


Table 7: Crude and product elasticity of demand estimates

Product	Price elasticity of demand estimates
Crude	OECD regional short run crude elasticities, weighted by regional crude demand -0.03
Gasoline	Short run estimate based on US demand -0.06
Diesel/Gas Oil	Gasoline elasticity as a proxy -0.06
Aviation fuel	Short run consumer aviation elasticity reported by DfT, adjusted to reflect the share of aviation fuel costs in total aviation costs. -0.06

Source: OECD[19]; US Congressional Budget Office[20]; DFT[21]; Air Transport Association[22]

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19 OECD (2009). "Recent Oil Price Movements – Forces and Policy Issues", Economics Department Working Papers No. 737, 2009

20 Congressional Budget Office (2008), "Effect of Gasoline Prices on Driving Behaviour and Vehicle Markets"

21 Department for Transport (2009), "UK Air Passenger Demand and CO_2 Forecasts", 2009.

22 See http://www.nytimes.com/2008/06/11/business/11air.html?_r=1 for the assumed share of aviation fuel costs in total aviation costs

In addition to elasticity estimates, calculating the impact of a supply shock on prices requires an understanding of the size of the relevant affected market. World demand for the product in question can be used to calculate the size of the total world market. However, some parts of the market will be initially relatively insulated from a supply disruption. This might be because of geographic distance or in the case of refineries which only produce for domestic consumers, which would only experience changed price incentives once the relative scarcity of product reached their internal markets. Full price effects may therefore take up to six weeks to diffuse through the whole market. The immediate price spike following the disruption may therefore reflect the impact on a smaller subsection of the market. The size of the immediately affected market will depend on the location and nature of the disruption, and on trade patterns.

4.2 Interruption Scenarios: definition and significance

We have developed a number of scenarios to test the resilience provided by domestic refining capacity in the event of a supply interruption, which we have illustrated in Figure 27 below. We have selected interruptions which would have a significant effect on the UK, either due to the disruption of supply from a key trading partner or by impacting a producer of wider significance to global crude or product market.

That said, we have deliberately avoided analysing catastrophic interruption scenarios, such as a blockade of the Strait of Hormuz. Ninety percent of oil exported from Gulf producers is carried on oil tankers through the Strait, which accounts for roughly 40% of all globally traded oil supply[23]. This represents approximately 20% of world demand. An interruption of this magnitude would have severe consequences for world oil markets, and would create intense pressure for a political response.

In general, catastrophic interruptions could be considered to be those of a scale and duration sufficient to exhaust available spare capacity and stocks, and lead to significant physical supply interruptions. The volumes involved will therefore depend on the prevailing level of spare capacity. Assessing the risks of such interruptions is complex and highly subjective. A risk assessment using an expert panel was conducted in 2005 for the US Department of Energy by the Energy Modelling Forum at Stanford University. This concluded that at least once in the next ten years, the probability of a net disruption (including any available offsets such as spare capacity) of over 2mbd lasting for at least six months was approximately 70%. The probability of a net disruption of over 5mbd was around 35%. The conclusions of the study are shown in Figure 25 below.

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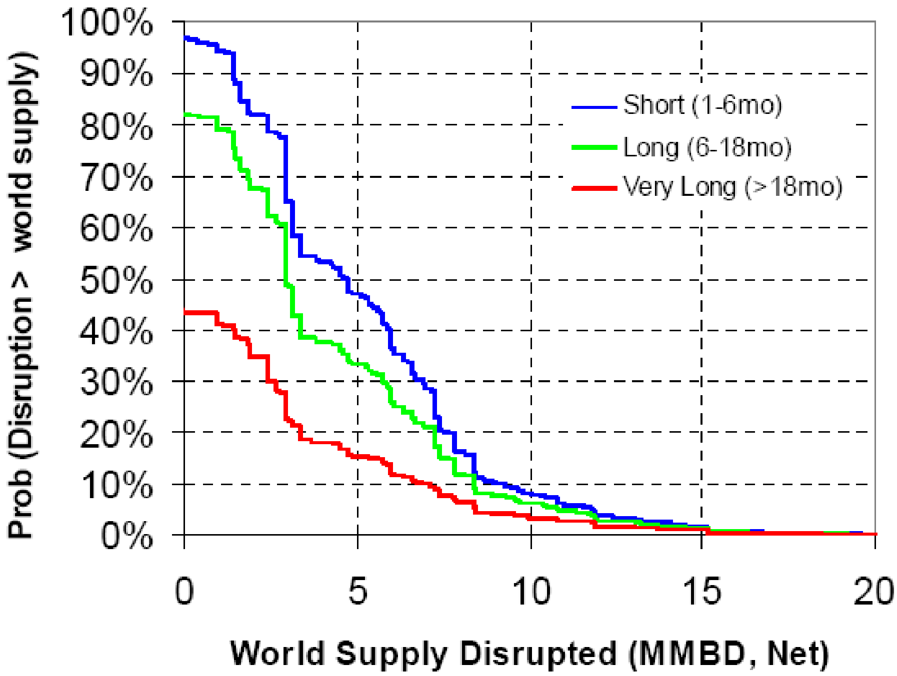
[23] See http://www.reuters.com/article/idUSL0715889720080107

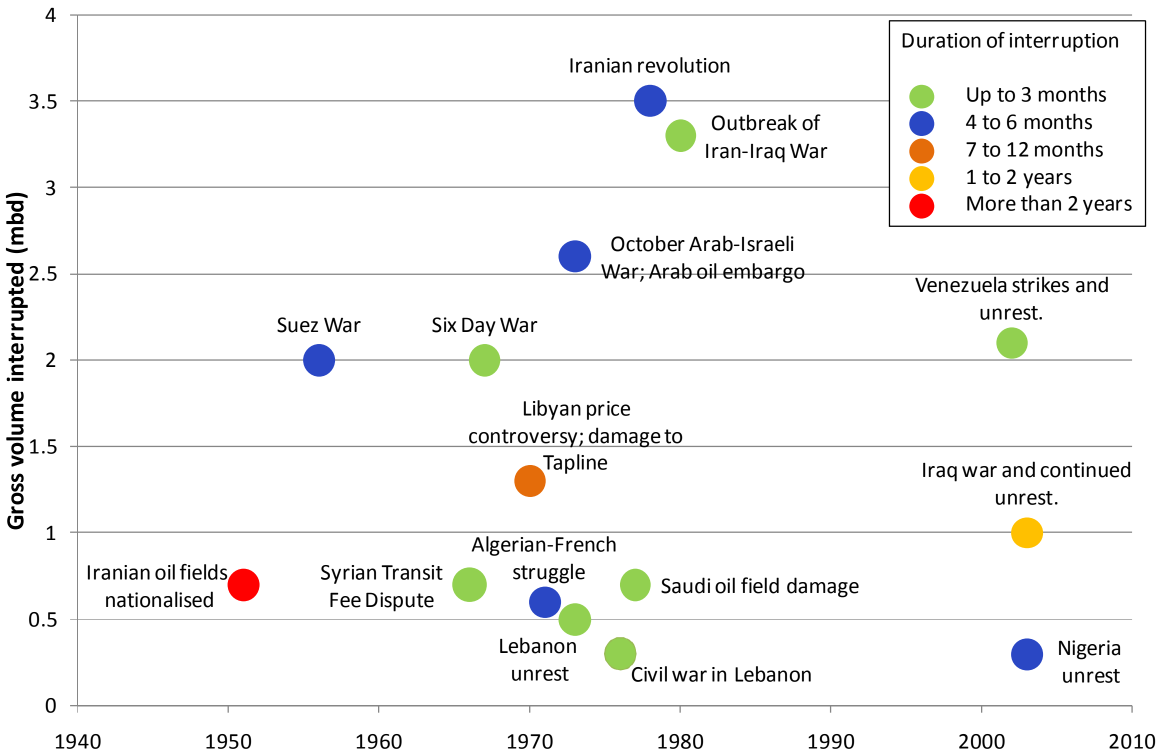
Figure 25: Probability of a oil market disruption, University of Stanford Study



Source: Energy Modeling Forum, Stanford University

That said, a review of crude oil interruptions since 1951 shows that there have only been three instances of interruptions of greater than 2.5mbd gross volume (that is, excluding any offsets). All of these were less than 4mbd, as shown in Figure 26. This emphasises the difficulty of understanding the risks of very significant interruptions.

Figure 26: Global crude oil supply disruptions since 1951

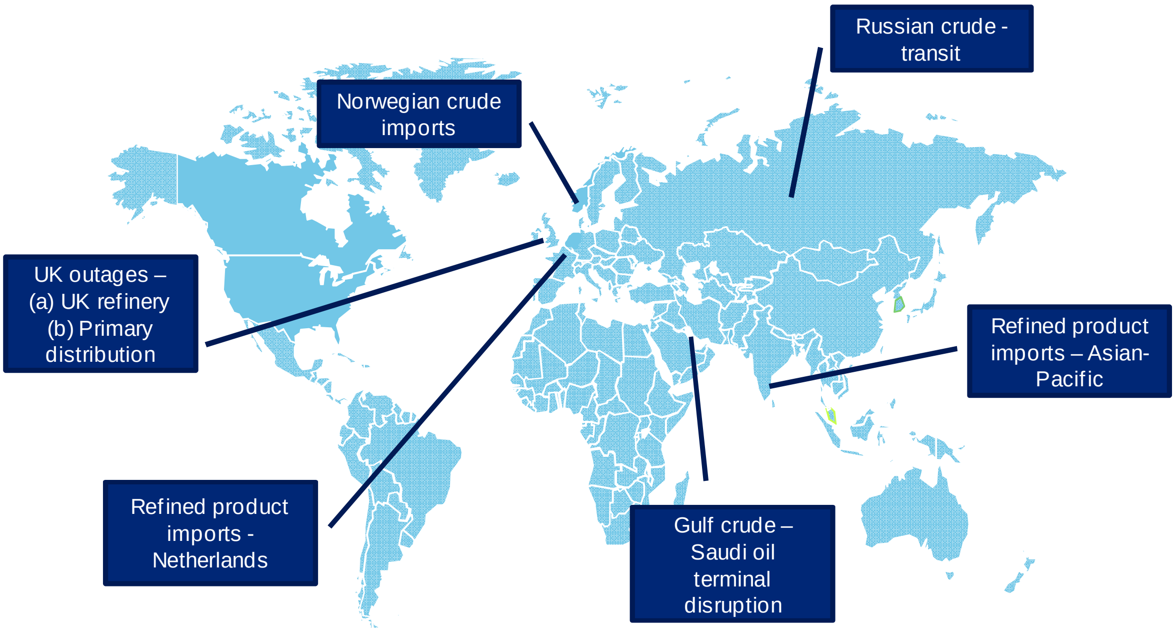


Source: EIA

Catastrophic interruptions would have negative effects on both crude and product markets, and therefore offer fewer insights into the relative advantages of domestic refining capacity and product imports. There are also few domestic policy options available to mitigate against a very significant interruption. The key mitigation – at least for a short-term interruption – is a co-ordinated release of emergency stocks via the IEA emergency response mechanism. We have therefore confined our discussion to less dramatic interruption scenarios, although we do discuss in Section 7.2 the benefits of domestic refining capacity in the event of a complete disruption to world markets.

The scenarios we have covered are highlighted in Figure 27 and explained further below.

Figure 27: Supply interruption scenarios



Our scenarios are intended to be representative of the possible volumes of supply which could be disrupted from each source. Although we have specified distinct causes of each interruption for the purposes of our analysis, there are a number of alternative scenarios which could lead to disruption of similar magnitude. The indicative probability of interruption is intended to represent the probability of a disruption of this magnitude occurring, rather than the probability of the specific incident occurring.

In the remainder of this section, we discuss for each of these interruption scenarios:

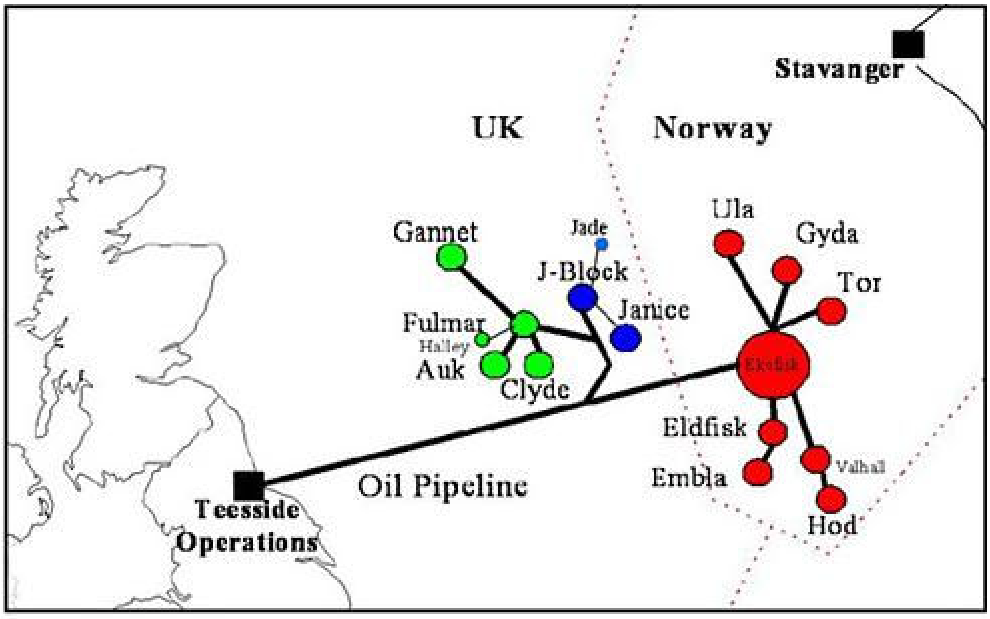
- possible causes of an interruption of this nature;
- the volume and type of production that is disrupted;
- how duration of the interruption; and
- the likelihood of the interruption.

4.2.1 Norwegian crude imports

More than half of UK crude imports come from Norway, making up almost 40% of total UK crude demand. Although this proportion is set to diminish as Norwegian production declines, imports from Norway are still likely to make up between 32% and 21% of UK crude demand in 2015 and 2030, respectively, under base refining capacity assumptions.

We have considered a significant interruption to crude oil imports from Norway by examining the impact of an incident affecting the Norpipe pipeline. This pipeline carries crude from a number of UK and Norwegian fields – including the Greater Ekofisk fields – to the Teesside processing and export facility operated by Conoco-Phillips. Here, the crude is stabilised and shipped to either UK refineries or to export destinations. Although oil is also transported from Norwegian fields to the UK via tanker, a relatively large proportion of Norwegian imports are likely to come via the Norpipe pipeway given the transportation cost savings.

Figure 28: Norpipe oil pipeline system overview



Source: Rigzone (www.rigzone.com)

The pipeline has a net capacity of around 900kbd, but the receiving facilities restrict capacity to about 810kbd. In 2008, the plant processed around 732kbd from the pipeline, of which some 71kbd originated from UK fields[24]. This volume represents approximately 1% of the world's daily crude production in 2008 (IEA, WEO 2009).

Flow through the pipeline could be disrupted by a range of incidents. Damage to the pipeline, for example by cracking caused by corrosion, could take between three and six weeks to repair, given the subsea nature of the pipeline. More substantially, an incident such as a major offshore pump failure could disrupt the pipeline for considerably longer. A fire which damaged both the pump and the substructure would cause damage which would take at least 6 months to repair. We note that a pump station fire in the vicinity of the Norwegian fields would be likely to disrupt only the Norwegian flows through the pipe. The tie-in point for UK fields is located about 50 kilometres downstream of Ekofisk, and is likely to have its own pump system which could still operate if the upstream section of the pipeline was sealed off.

The likelihood of an incident of this severity occurring is low, given the importance of the pump stations to the overall operation of the pipeline and high levels of maintenance. We have therefore assumed an incident of this nature to be a 1 in 30 years event.

[24] Data for UK production are provided by DECC; Norwegian field production values are obtained from Deloitte's Petroleum Services Group database.

Given the flows through the pipeline, a major pump station incident upstream of the UK tie-in point would disrupt roughly 660kbd of Norwegian production. No data is available on the share of this production absorbed by the UK rather than being exported to other destinations. However, because of transportation cost savings, it is likely that a considerable proportion is imported into the UK. We assume for the purposes of this analysis that some 80% of Norwegian imports to the UK are routed through the pipeline.

Table 8 below summarises the total volumes of Norwegian crude disrupted in this scenario. We have assumed that flows through Norpipe decline in line with IEA assumptions of the overall decline in Norwegian production. However, it is possible that additional fields might be tied in to the pipeline over time, so the flow values may decrease at a slower rate.

Table 8: Disrupted volumes of Norwegian crude imported

	2008	2015	2030
Production disrupted	Crude oil		
Total volumes disrupted (kbd)	660	510	330
Duration of interruption	6 months		
Probability	1 in 30 years		

4.2.2 Russian crude

The UK imports approximately 6.5mt per year of Russian crude oil, representing 10 percent of total crude oil demand. These imports are predominantly transported from the Baltic port of Primorsk, although they can also come from Black Sea ports via the Mediterranean Sea.

The causes for a supply disruption of Russian crude oil fall into two broad categories. First, a short to medium term interruption may result from weather, transportation or production problems. Second, a potentially longer-term supply restriction could result from a politically-motivated embargo on supplies.

Politically-motivated supply embargo

Russia is heavily dependent on revenues raised from the export of both crude oil and oil products. However, it is not unknown for the withholding of such supplies to occur at times of political discord with neighbouring countries and trading partners.

That said, there has so far never been an incident where Russia has withheld the sale or supply of crude oil or products to the UK. Where such actions have been taken (with other trading partners) this has usually been caused by non-payment for goods or services. It is considered highly unlikely that the UK would default on payments for crude oil or oil products delivered to the UK. This is particularly the case as most trade deals are confirmed for sea-borne deliveries prior to the physical delivery of cargoes. Most non-payment issues with Russia have occurred with countries receiving crude oil, products or natural gas via pipeline where payments are linked to measured deliveries in arrears.

Of more concern would be the suspension of supplies of Russian crude oil supplies to Europe as a whole, or, say, to the European Union. The causes of such political events may not be likely but are not impossible. In particular, a major disagreement over military matters – for example, the expansion of NATO to include former Soviet Union countries – might be sufficient to precipitate such a response from Russia. However, Russia would need to balance such a response against the loss of revenues from the sale of crude oil to Europe as a whole. Given the dependence of the Russian economy on oil revenues, we consider that such a scenario is fairly unlikely and so have examined instead a technically-based interruption scenario.

Technically-based supply interruption

Technical and weather-related problems could potentially lead to a complete cessation of exports via Baltic ports. These could include:

- Extreme weather leading to non-operation of loading jetties and restricting vessel movements;
- Technical problems at the loading jetties; and
- Pipeline failure or pumping problems.

Such extreme weather events and/or technical constraints are relatively rare. These are major export routes for Russia so the transportation infrastructure is relatively well maintained and much of the shipping is designed for operation in hostile environments (for example, the use of ice breaker class vessels). This suggests that any such interruption is likely to be no more frequent than a 1 in 10 year event and last for a period of weeks rather than several months.

As a specific interruption scenario, we have considered an interruption to the Baltic Pipeline System (**"BPS"**) leading to the Baltic port of Primorsk. This might be due to a technical issue or to pipeline sabotage, and is likely to lead to no more than a three week interruption.

The current throughput of Primorsk is 1.5mbd of crude oil, and this is estimated to increase to 2mbd by 2020 (ISAI, 2009). Table 9 summarises the volumes which might be disrupted by an interruption to the BPS, as well as the key features of the interruption scenario.

Table 9: Interruption to Russian crude imports due to BPS incident

	2008	2015	2030
Production disrupted	Crude oil		
Total volumes disrupted (kbd)	1,000	1,000	1,000
Duration of interruption	21 days		
Probability	1 in 10 years		

4.2.3 Asian-Pacific refined product imports

The UK imports oil products from the Asian-Pacific region. The most significant of these imports is for kerosenes, mostly as aviation fuel to meet some of the substantial deficit in southern England. Imports of aviation fuel from Asia recently have totalled about 2.8mt per year, mostly from Singapore, India and Korea.

The UK's reliance on aviation fuel imports will increase between now and 2030. Demand for aviation fuel is forecast to increase from 12.6mt in 2008 to around 18mt in 2030, and even to as much as 20mt under high case assumptions. Due to increasing refinery capacity in India in the next few years, most of which will be export-orientated, it is likely that the UK's reliance on aviation fuel imports from India will increase. We have therefore considered the impact of an interruption in exports from India, potentially due to a major refinery shutdown/outage in one of the export-orientated refineries.

Reliance Industries operate two very large export-orientated refineries in the Jamnagar region and it is possible that most of the UK imports from India will be from one of these refineries. Each of these major 600 kbd (30 million tonne per year) refineries produce in the region of about 2mt to 3mt per year of aviation fuel.

Most incidents tend to have a fairly localised effect on a refinery. However, a major fire which destroyed extensive areas of process plant and related control systems could lead to a sustained loss of production. Such a major event may cause a refinery to be out of production for periods in excess of six months, and possibly up to a year or more. We have therefore considered the impact of a refinery incident which disrupts all production for a six month period. There is a relatively low probability of such a major incident occurring at a particular refinery. However, when looked at more generally, there is a greater probability of a major incident occurring at a representative large refinery producing considerable volumes of aviation fuel exports. We have therefore estimated the probability of this event occurring as a one in ten years' event.

Table 10: Interruption to Indian imports

	2008	2015	2030
Production disrupted	Aviation fuel		
Total volumes disrupted (kt/day)	6.8kt/day	6.8kt/day	6.8kt/day
Duration of interruption	6 months		
Probability	1 in 10 years		

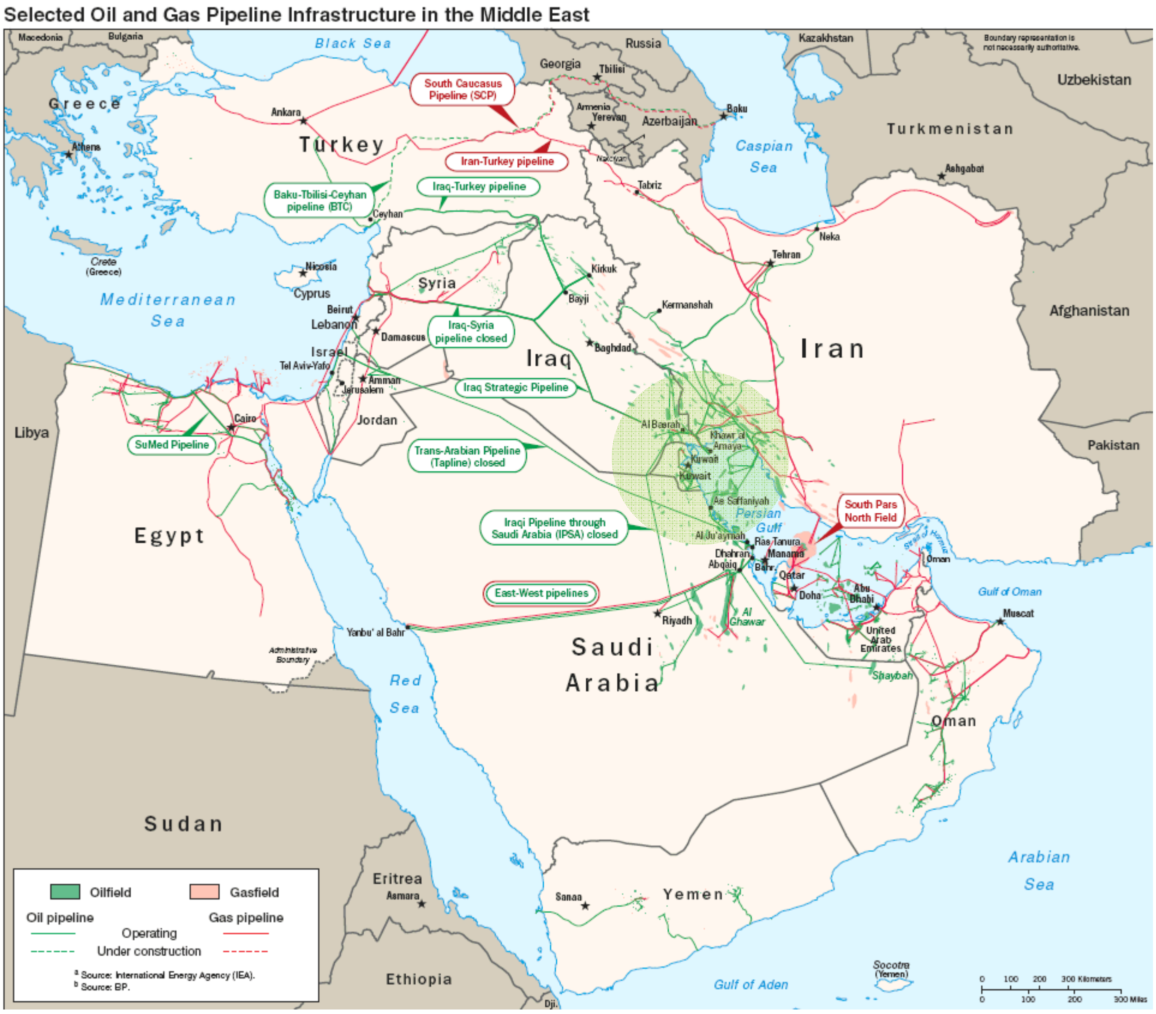
4.2.4 Interruption to Saudi crude exports

Saudi Arabia is at the heart of world crude production. It was responsible for 11% of global crude output in 2008[25], with much of this being sour crude.

The core of the Saudi Arabian oil sector is located on the east coast of the country. Key fields are located in the east including Al Ghawar, the largest onshore field in the world, and Safaniya, the third largest field in the world. The area is also home to the largest processing centre in the world – the Abqaiq facility – which has a processing capacity of 7mbd and processes two thirds of Saudi crude. The area is also key to Saudi export distribution with the world's largest offshore export facility at Ras Tanura and the large Ras Al Ju'aynah terminal. The crude from these terminals passes through the Strait of Hormuz. Together with the crude and product from surrounding Gulf States, this traffic represents over 16mbd of oil.

[25] IEA, World Energy Outlook, 2009

Figure 29: Selected oil and gas pipeline infrastructure in the Middle East



Source: EIA

The scale and geographic concentration of these resource deposits, processing facilities and transportation nodes raise the magnitude of any disruption to a potentially catastrophic scale. The Journal of International Security Affairs estimates that a total interruption in the form of a successful aerial terrorist attack on multiple targets, resulting in a full interruption for six months, could have a global economic impact of the scale of a Radiation Dispersal Device (dirty bomb) attack in New York[26]. Unsuccessful attacks on these facilities have been attempted in the past, such as the unsuccessful attempted bombing of the Abqaiq facility in 2006 and attempts to target a pipeline feeding Ras Tanura in 2001[27]. This vulnerability is exacerbated by the political instability in the region. Previous incidents include the Arab-Israeli War, the Gulf Wars and the Iranian Revolution,

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[26] http://www.iags.org/n0111041.htm, The Journal of International Security affairs, 2003

[27] http://www.iags.org/oiltransport.html

all of which have been estimated to have had some of the largest crude disruption effects since 1951[28].

However, as discussed previously, this scale of interruption is too large to include in our analysis. It is beyond the scale by which it would be possible to measure the impact of the UK's refinery capacity and beyond a level by which either crude or product markets would be able to operate effectively, and would be likely to prompt an international geopolitical response.

We have instead analysed a more moderate disruption at one of the major Saudi supply terminals in the Gulf. There are a number of potential causes of such a disruption, including technical failure or accidents such as a crude tanker collision with a jetty. Although many of the Saudi export terminals have crude handling capacity of several million barrels per day, Saudi Arabia has sufficient inbuilt flexibility in export routes to reduce the likely volumes disrupted by such an interruption. For example, the 5mbd Petroline flowing East to West from Abqaiq to Yanbu is maintained specifically for mitigating a Strait of Hormuz disruption scenario. It is thought to be currently less than 50% utilised[29] and so at least 2.5mbd of flow capacity is available to provide relief in the event that an eastern export terminal is disrupted. Yanbu has a handling capacity of approximately 4.5mbd of which just over 2mbd is currently thought to be in use. This is sufficient to cope with a partial disruption of a terminal. It has been noted that when a further 12 smaller under-utilised terminals are included, Saudi has between 3 and 4mbd of spare exporting capacity[30]. This would be sufficient to cope with a full disruption at Ras Al'Jayumah, for example.

Given these alternative export routes, we have assumed that a terminal interruption is unlikely to take more than a net volume of 1mbd of crude handling capacity out of the Saudi infrastructure. This represents approximately 12% of export volumes.

Historically, there has been some significant outage to Saudi infrastructure roughly every five years, given the concentration of oil distribution apparatus in the area. We therefore assume that a volume interruption of this magnitude could be considered as a one in five years event.

Table 11: Summary of Saudi Arabia crude interruption

	2008	2015	2030
Production disrupted	Crude		
Total volumes disrupted (kbd)	1,000	1,000	1,000
Duration of interruption	6 months		
Probability	1 in 5 years		

[28] http://www.eia.doe.gov/security/distable.html

[29] http://www.eia.doe.gov/emeu/cabs/Saudi_Arabia/OilExports.html

[30] ibid

4.2.5 Refined product imports from the Netherlands

The Netherlands acts as a large trading hub for North-West Europe. Along with Amsterdam, the port of Rotterdam plays a key role in trading activities. It imports approximately 100mt of crude annually for its own domestic refineries and for pipeline-fed refineries in Germany and Belgium. It also both imports and exports refined products, with 36mt imported and 22mt exported in 2008[31]. Rotterdam has significant volumes of storage, partly due to its role as the delivery point for gas oil futures contracts.

The Netherlands is also a major provider of oil products to the UK. In 2008, the Netherlands imported over three mt of product to the UK, mostly as middle distillates. The port of Rotterdam was used primarily for the middle distillate and fuel oil exports to the UK while Amsterdam was more focused on gasoline trade.

Table 12: Product imports from the Netherlands in 2008

Product	Imports from the Netherland (kt)	% of UK imports	% of demand
Diesel/gas oil	1,785	23.9%	6%
Aviation fuel	227	2.8%	2%
Gasoline	859	30.3%	5%

Source: IEA

An interruption to Dutch exports could result from a production stoppage at one of the Dutch refineries, or from an incident at one of the ports. A major production stoppage at one of the five main refineries in the Netherlands – for example, through industrial action, fire or other operational difficulty – might impact up to 30% of the Netherland's total exports of middle distillate. However, an interruption to product exports via a Dutch port is likely to constitute a more significant threat to UK product supplies, as the Netherlands exports more than its domestic middle distillate production. This could arise through industrial action, adverse weather or a major incident such as an oil or chemical spillage or the blockage of a shipping channel through a ship running aground.

We have considered an interruption to the port of Rotterdam, as the most significant port in terms of exports to the UK. It is conceivable that a variety of events might limit vessel loadings or departures. As an illustration, we have considered the impact of a serious marine transportation incident, such as an LNG ship running aground[32] in the port's main channel. Due to the explosive nature of the cargo, it is likely that such an incident would result in a complete channel closure for up to three weeks. A similar interruption would be an oil tanker running aground and spilling its cargo, necessitating a major clean-up operation.

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[31] Port of Rotterdam, Port Statistics, 2008

[32] The Gate LNG import terminal in Rotterdam is currently under construction with planned completion in 2011.

Shipping incidents are not uncommon. In particular, historic data on LNG accidents suggest that as the product is increasingly heavily traded, accident occurrences are rising as are their severity. We have therefore assumed an incident of this nature to be a 1 in 10 year event.

Table 13: Summary of Rotterdam interruption

	2008	2015	2030
Production disrupted	Diesel/gas oil		
Total volumes disrupted (kt/day)	29kt/day	29kt/day	29kt/day
Duration of interruption	3 weeks		
Probability	1 in 10 years		

4.2.6 UK refinery outage

Refineries play a key role in UK oil distribution. Not only is their output a source of refined product, but they are also a key node in the distribution network as they often provide ingresses into the pipeline network and large storage facilities. Furthermore, they currently provide a key of import for refined products; it is estimated that approximately two thirds of refined product imports enter the UK through terminals attached to refineries. The loss of a major refinery facility may therefore have a significant impact on the availability of product and on the stress on the distribution network, both locally and nationally.

Overview of risks of refinery interruption

A refinery might be unexpectedly closed[33] for a protracted period of time due to a number of factors, including the following:

- **Mechanical failures.** Interruptions may result from plant or unit closure due to damage or safety concerns. Even the closure of a single unit may heavily impact other units due to storage, throughput and bypass constraints[34], if the shut-down component is a major one.
- **Accidents.** Accidental damage can result in either the destruction of infrastructure or closure for an extended time due to Health and Safety concerns. Accidents can often also lead to fires which can cause much wider secondary damage and disruption, such as the incidents at Coryton in October 2007 and Fawley in July 2007.
- **Industrial action.** Strikes by employees have caused refinery closures in the past. Official strikes are often preceded by the unions consulting with their members and arranging strike

[33] We have not considered planned shutdowns, which can last several months. These are usually planned for well in advance and measures – such as stockpiling – put in place to mitigate against any disruptions.

[34] http://www.eia.doe.gov/oiaf/servicerpt/refinery_outages/SROOG200701.pdf

ballots, which provides time to prepare contingency options. However, uncertainty remains on the length of disputes and consequently on the scale of the contingency responses that will be required. The disruption may also continue after the strike is over due to the time required to restart the facility. For example, although the 2008 Grangemouth industrial disputes lasted only two days, it was estimated to have taken two or three weeks to get back to full operation. Occasionally strikes may be unofficial, so-called "wildcat strikes". These actions allow little planning due to a lack of notification. For example, Lindsey refinery workers held wildcat strikes in 2009 over the awarding of construction contracts which were supported by sympathy strikes at Stanlow refinery.

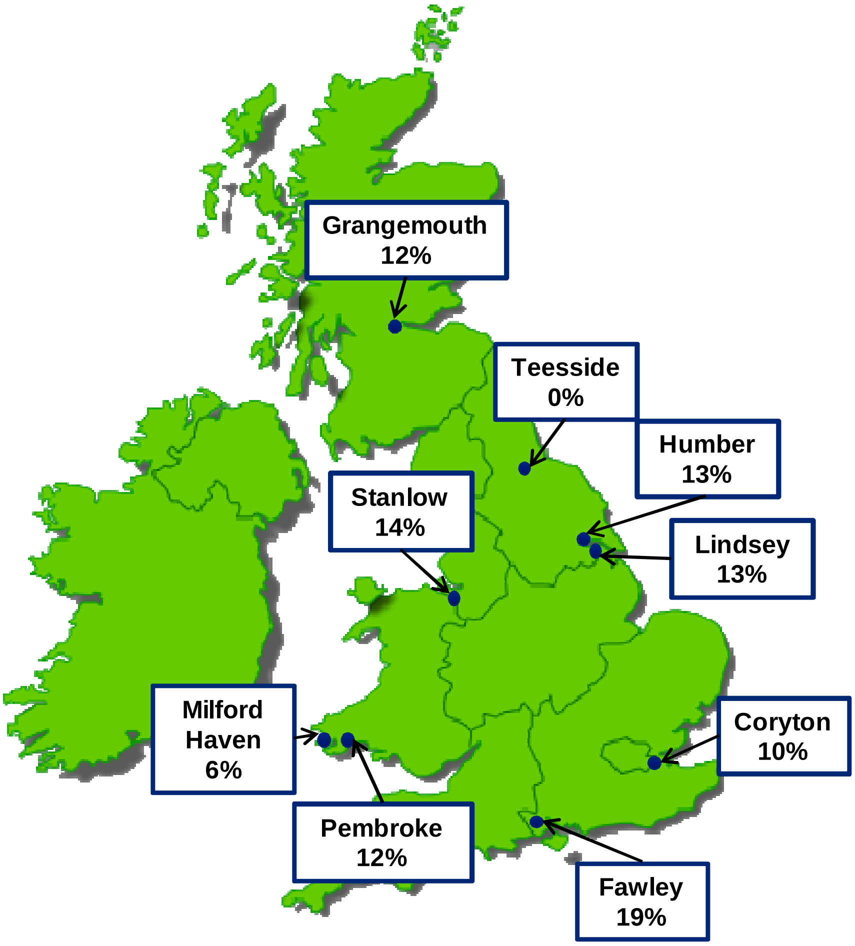
- **Maintenance Overrun.** Planned maintenance occurs regularly on refinery premises. This may involve temporary closure of certain units or the entire refinery being offline for wholesale maintenance and checks every few years. For example, Stanlow refinery was fully closed for major maintenance in January 2007 until March 2007.[35] While these planned closures might not be expected to cause problems themselves, they would further tighten infrastructure capacity elsewhere and exacerbate supply issues if an unplanned disruption were also to occur. During these planned down times, problems may be located that cause extended downtime of the refinery or force its closure until they are resolved.

Selected Interruption Scenario

We have considered an interruption to one of the UK's refineries, and have selected Fawley as our representative refinery. It is the UK's largest refinery and accounts for 18% of total UK refinery output, as shown in Figure 30 below.

[35] http://uk.reuters.com/article/idUKL1941369020070119

Figure 30: Location and current capacity of UK refineries



Source: Refining capacities from DECC, Digest of Energy Statistics UK
Note: Teesside is shown as having no capacity given its recent closure.

We consider an unscheduled disruption to the entire refining unit caused by mechanical failure. As part of this scenario we assume that pipeline and docking facilities are unaffected to isolate the impact of a loss in refining capacity. This allows the facility to continue to act as normal as an import terminal.

The disruption is assumed to last three weeks, although the duration of an unplanned shutdown due to significant mechanical failure could be much longer. Although this is a comparatively short disruption, this would be considered a major infrastructural event given the size of the facilities and its proportion of the UK's refinery stock. Though an interruption to Fawley of this specific nature is relatively unlikely, we select Fawley as an example of a more generic refinery disruption. As such, we consider this sort of disruption has a 1 in 10 year probability of occurring on the basis of the risks of refinery interruption outlined above.

Table 14: Summary of UK refinery interruption

	2008	2015	2030
Production disrupted		Refined product	
Total volumes disrupted		266kbd processing capacity	
Duration of interruption		3 weeks	
Probability		1 in 10 years	

4.2.7 UK primary distribution

The interconnections between refineries and demand centres are composed of a network of import terminals, pipelines, haulage routes, rail connections and coastal shipping routes. A disruption to most aspects of the primary distribution system would have the same effect whether the product being distributed had originated from a refinery or from product imports. In order to contrast the relative security of supply benefits of refineries and imported products, we confine our discussion to a disruption at an import terminal.

Overview of risks of terminal interruption

There are a number of interruption risks associated with sea terminals. We consider each in turn, and where appropriate, make comparisons to refineries regarding the relative probability and severity of a disruption occurrence:

- **Mechanical failures.** As with a refinery, it is possible that a combination of erosion, corrosion and wear caused by the flow of product may cause a mechanical failure in the onsite facilities. Taking terminals to be relatively less mechanically-intensive and complex, this may pose a smaller risk of disruption compared to a refinery.

- **Accidents.** With vehicles, individuals and machinery operating on site it is possible that accidental damage to equipment such as truck gantries or port berths may occur. As a terminal's import facilities are very similar to those at a refinery, we expect the probability of disruption to be broadly similar.

- **Industrial action.** Owing to the comparatively less complex and intensive processes at import terminals in comparison to refineries, staff numbers will be lower and, though only comparatively, lower skilled in nature. In particular, the roles would be expected to be less segmented than in a refinery; for example, specialist staff are required to work on specific cracker units in a refinery. As a consequence of these combined factors a terminal would be expected to be relatively less prone and less severely affected by industrial action.

- **Maintenance.** Given the less complex nature of terminals, it is expected that they will require less planned and unplanned maintenance.

Selected Interruption Scenario

We have considered an interruption to one of the UK's import terminals, and have selected the Bristol Aviation Fuel Terminal (**"BAFT"**). This is on the basis of the following characteristics.

- **Large facilities**. BAFT is operated by Kuwait Petroleum, and handles large volumes of aviation fuel imports from Kuwait of approximately 1.7mt per year.
- **Concentrated product impor**t. BAFT is a substantial source for aviation fuel, but it has low volumes of other petroleum products. As a consequence, despite its relatively small size, a BAFT interruption has the potential to disrupt considerable aviation fuel supplies.
- **Pipeline ingress**. Disruption to the throughput of BAFT also has an impact on delivery into the pipeline network. BAFT has a single inlet into the pipeline network (the OPA) which flows straight to the London airports.

We have considered a disruption to the terminal resulting from a shipping accident, for example a vessel colliding with the dedicated kerosene berth at BAFT. This could lead to a disruption of up to three weeks as the berth is cleaned and repaired. The probability of a disruption of this duration is estimated as a 1 in 10 year event.

A three week interruption to BAFT would disrupt approximately 70kt of aviation fuel imports, as the product tankers from Kuwait arrive approximately every 15 days and are of a 70,000 dwt capacity. As a worst case scenario, we assume that the shipping incident involves a fully laden aviation fuel tanker, so that there is an immediate disruption of 70kt of aviation fuel.

Table 15: Summary of UK terminal interruption

kbd	2008	2015	2030
Production disrupted		Aviation fuel	
Total volumes disrupted		70kt	
Duration of interruption		3 weeks	
Probability		1 in 10 years	

5 Mitigating actions to limit impact of supply interruptions

This section sets out a range of mitigating actions that can be used to compensate for a supply interruption and minimise the potential impact on consumers. It also assesses the possible constraints of each action that may reduce its effectiveness in the context of a disruption to the UK market.

5.1 Global crude production capacity

In the event of a crude supply disruption, the availability of spare crude production capacity and how quickly this can be brought to the market will be important in minimising any potential impact of a disruption. Most independent oil companies ("**IOCs**") and many national oil companies ("**NOCs**") operate at close to full capacity. However, recently Saudi Aramco has developed significant flexibility in its production, in part due to Saudi Arabia's strategic objective of being able to play a stabilisation role in global oil markets.

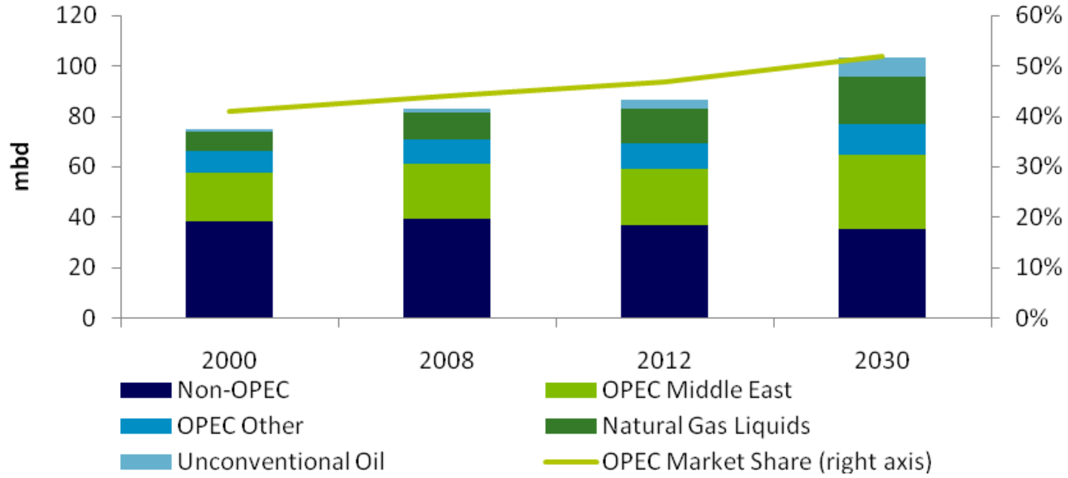
With the reduction in oil demand experienced in 2009 as a result of the global recession there is, at present, considerably more spare production capacity compared to the tight market seen in 2004-2007. It is estimated that around 5mbd of effective spare crude production capacity existed at the end of 2009[36], with the majority of this in Saudi Arabia. However, most of Saudi Arabia's spare capacity is for sour crude, and as discussed earlier, UK refining capacity is inadequate to support significant changes in the crude slate.

The impact of the global recession on demand has also hit the growth in global crude production with investments in a number of projects either being deferred or cancelled. There is also evidence of cuts in capital spending on existing oil fields, which may lead to faster rates of production decline in mature fields such as those in the North Sea. This is likely to reduce spare capacity in the short term for the sweet crude that is mainly used in UK refineries.

Looking ahead to 2015 and beyond, the main changes in global crude oil production will be a shift towards a greater proportion of crude oil production from OPEC countries, driven in part by a decline in capacity from non-OPEC countries. This includes counties such as the UK, Norway, Mexico and the USA where production is expected to decline in the period to 2030. Growth in non-OPEC production in countries such as Azerbaijan, Kazakhstan and Brazil will in part counteract this decline in other countries. These trends are shown in Figure 31 below.

[36] IEA, Oil Market Report, December 2009

Figure 31: Source of oil production (2000–30), mbd; OPEC % market share (2000–30)



Source: IEA

As discussed in Section 2.3, the UK will need to replace its own production and imports from the North Sea with imports likely to be sourced from North / West Africa and the Caspian region. The UK's advantage in terms of proximity to sources of crude imports (notably Norway) will be diminished in the future which may reduce its ability to access spare capacity if a supply disruption occurs. The issue of access to crude is discussed in Section 5.2.

The level of spare capacity in crude production will depend greatly on how demand recovers following the decline in 2009. By 2015, if growth in demand is slow, then the existing level of spare capacity may be broadly maintained as discussed in Section 2.1.5.

Beyond 2015 there is greater uncertainty on the level of spare capacity. Uncertainty in demand growth may lead some oil producers to make fewer investments in new capacity until they see clear evidence of a return to more sustained growth in demand. This could increase the probability of tight supply with limited spare capacity, such as that seen in 2003-2006, at some point in the next 20 years. Regardless of the actual level of future spare capacity, Saudi Arabia will remain the principal source of spare crude oil production in the world.

5.2 Access to alternative crude supplies

Accessing and availability of crude

In the event of an interruption to crude supply, any increased production is likely to come from Saudi Arabia as the only producer with any significant spare capacity (though we recognise this may have changed by 2030). Saudi Arabia also keeps considerable volumes in the form of stocks in various strategic locations around the world to enhance energy security[37].

[37] According to the EIA, Aramco owns or leases oil storage facilities around the world, in places like Rotterdam, Sidi Kerir, South Korea, and the Philippines. Reuters reported in December 2009 that Saudi Arabia has ended its long-held

However, Saudi Arabia sells almost exclusively on what is known as a term contract basis to established customers, often with restrictions on the ability of the purchaser to resell. Crude oil is traded through a mixture of longer term, "term" contracts, and spot market contracts. Term contracts are made for a period, normally 12 months, and are often rolled over at the end of the period. These contracts specify volumes and pricing mechanisms, such as the prevailing spot price of a benchmark crude less a set value. Certain producers, such as Middle Eastern producers, are more likely to sell on the basis of term contracts. In contrast, North Sea, African and Russian producers are more likely to sell on a spot basis. Most companies will purchase via a mix of spot and term contracts, with Atlantic Basin consumers tending towards a greater proportion of spot purchases and more conservative Asian consumers relying more on term contracts.

Therefore, in the event of a crude supply interruption, any increase in Saudi oil production is likely to be released to existing term contract customers. This will then filter through to the rest of the market, as these customers are then able to release supplies from other sources into the market. Discussions with traders have indicated that the market is now far more transparent and open than even 15 years ago. Price signals drive market responses, and market players have little incentive to hoard but will make product available to the highest bidder. There are also few restrictions in terms of parties that trade with each other, with access being driven through prices and ownership not being a significant driver. However, there is a growing trend from a number of countries – such as China – towards increasing security through ownership production assets, but it is not clear how far this will impact the liquidity of markets. In the case of crude, this threat may be mitigated by the fact that spare capacity is in the hands of Saudi Arabia and no single consumer owns this.

If there is insufficient spare crude capacity in the market to replace the lost production, price will determine access to the available production. Those with higher transport costs will be penalised, as will the less efficient refineries that are unable to pass on as much of the cost increase to their end consumers.

We note that the time required to access alternative crude supplies will depend partly on the region from which the crude is sourced, but also on whether cargoes which are already en-route can be diverted. Increased levels of trading means that there are large volumes of cargoes on the sea at any given time, which are often traded several times during their journey.

Ability of UK refiners to utilise alternative crude supplies

Following an interruption to a particular grade of crude, the price of grades that constitute immediate substitutes will shift linearly upwards as refiners demand replacement feedstock. The increased price differential between these grades and others will then lead refiners to substitute away from the grades experiencing increased demand. If, for example, the supply of relatively lighter, sweeter crude was disrupted, those refiners with the capability to process increased quantities of sourer feedstocks would be incentivised to substitute away towards a heavier, sourer slate. This process takes three to six weeks, as refiners would need to amend their mix of

lease for 5 million barrels of Caribbean oil storage, but has signed a deal to put "millions of barrels" of oil in commercial storage in Japan for no charge. See http://www.reuters.com/article/idUSTRE5BT2HR20091230 feedstock through re-running their optimisation models[38] and put in place new orders. Delivery lead times mean that most refiners will tend to make decisions relating to feedstock mix three to four weeks in advance of an actual change in feedstock utilisation.

Most refineries in the UK process light, sweet crude, partly due to the proximity of UK and Norwegian production in the North Sea. This can be seen by the composition of crude imports; with the exception of Russia and Venezuela, most imports are from region such as the North Sea, Libya, Algeria and West Africa which generally produce relatively high quality crudes. The UK slate is now much sweeter than previously; in fact, many refineries were originally built to run on Middle Eastern crude. As oil product specifications have become more onerous, in particular with the reduction of their permitted sulphur content, refiners have needed to invest in desulphurisation[39] capacity and/or switch to lower sulphur crude slates in order to meet required specifications. Environmental regulations governing refining emissions have also influenced refineries' choice of crude oil for processing.

There tends to be an economic benefit associated with processing sourer crude, as the market often discounts sour crude oils to the point at which refining margins are, in some circumstances, better for processing sour crude oil than sweet crude oils. As a generalisation, then, refiners who are running very high quality grades have technical, environmental or economic motivations for doing so. This suggests that UK refiners may have limited ability to process sourer crude in the event of a disruption to light, sweet crude, a point we discuss further in Section 5.3 below.

5.3 UK refinery production

Spare refining capacity can be used to ease supply disruptions by increasing throughput or changing the product yields. Utilisation of UK refineries, along with other European refineries, has decreased from a peak of around 86% in 2005 to just over 81% in 2008[40]. This decline in utilisation is expected to continue over the next five years, with the expectation that it could go down to mid-70% by 2015. Table 16 below shows the potential spare capacity by product at an assumed sustainable utilisation of 90%[41] under the 'base refining' and 'low refining' scenarios (assuming 2008 yields).

[38] These are mathematical models that represent the different refinery process units and qualities of the process streams. Based on relative prices of different crude grades and products, these models generate the optimal feedstock mix and resulting yields. These are generally run daily to continually optimise refinery economics, with the crude mix varied using different crudes held in storage.

[39] The addition of further hydrodesulphurisation ("**HDS**") capacity is a key way to enhance the capability to run more sour crude oils. In addition to HDS units, other sulphur emission abatement techniques and technologies are often needed to process more sour crude oils; all of these are reasonably well proven, although they are expensive to install.

[40] Here, utilisation is measured in terms of crude input. In reality, utilisation is around 5% higher as throughput also includes partially processed feedstock.

[41] This would equate to around 95% utilisation when partially processed feedstocks are included.

Table 16: Spare capacity in UK refining

Year	Units	Base refining scenario 2008	2015	2030	Low refining scenario 2008	2015	2030
Refining capacity	mbd	-	1.70	1.70	-	1.24	1.24
Assumed utilisation	%	81.5%	81.5%	81.5%	81.5%	81.5%	81.5%
Total Production (excl. Naptha & LPG)	m tonnes	67.4	65.1	65.1	67.4	47.6	47.6
Assumed maximum capacity	%	90%	90%	90%	90%	90%	90%
Total spare capacity	m tonnes	7.0	6.8	6.8	7.0	5.0	5.0
Theoretical spare capacity by product (2008 yield)							
Diesel/Gas Oil (35.6%)	m tonnes	2.51	2.42	2.42	2.51	1.77	1.77
Aviation Fuel (8.7%)	m tonnes	0.61	0.59	0.59	0.61	0.43	0.43
Burning oil (4.1%)	m tonnes	0.29	0.28	0.28	0.29	0.20	0.20
Gasoline (26.9%)	m tonnes	1.89	1.82	1.82	1.89	1.33	1.33
Residual Fuel Oil (15%)	m tonnes	1.05	1.02	1.02	1.05	0.75	0.75

Note: theoretical spare capacity is estimated by calculating the difference between assumed maximum capacity and current utilisation, and then applying 2008 product yield values to this difference.

This implies that some spare UK refining capacity will be available in the future. However, there are number of issues that may limit the ability of UK refineries to respond effectively to a supply disruption given the way that UK refineries are operated.

Scope for adjusting crude slates

In the event of an interruption to sweet, crude supplies, UK refineries may be less able than other refineries with greater desulphurisation capabilities to switch to sourer grades. An increase in the proportion of sour crude would result in throughput reduction, as refinery operations would be severely compromised by any need to further process either feedstock (for example, feed for the FCC unit) or reprocess finished product to remove sulphur derived from sour crudes. There would also be a considerable impact on product yields. Yields from primary distillation capacity for the UK Forties crude blend are around 22.5% gasoline, 12.2% kerosene and 21.9% diesel/gas oil, with 40% residue. In contract, a heavy sour Venezuelan crude results in more than 80% residue. The use of sour crudes is also likely to result in increased operating costs due to increased corrosion from sour crudes. This suggests that UK refiners may be reliant on the ability of other refiners with more desulphurisation capability to reduce the quality of their own feedstocks and free up light, sweet crude.

The precise crude slate for most refineries is commercially sensitive and confidential. The table below indicates the possible breakdown of crude runs by UK refineries based on industry knowledge and refinery characteristics. These estimates indicate that five of the main fuels refineries have some limited ability to process sourer crude. In most cases this sour crude will be at least partly Russian Export Blend ("**REB**"), also referred to as Urals.

Table 17: Estimated breakdown of crude runs of UK refineries

Refinery	Distillation capacity (kbd)	% sweet crude processed	Comments
Petroplus Coryton	172	Around 80%	Some capacity to process sourer crude
Conoco Phillips South Killingholme	221	Likely to be largely sweet	Close to North Sea production
ExxonMobil Fawley	326	Estimated at around 2/3rds of slate	Some lubricants and bitumen production may favour more diverse crude slate, including some REB
Shell Stanlow	267	Around 80%	Some lubricants and bitumen production may favour more diverse crude slate including some REB
Total Humberside	221	Around 80%	Recent HDS project may permit higher amounts of sour crude to be processed
Ineos Grangemouth	196	Likely to be largely or entirely sweet	Connected to North Sea production via pipeline
Chevron Pembroke	210	More than 80% sweet	Some capacity to process sourer crude
Murco Milford Haven	106	Likely to be largely sweet	

Source: Oil and Gas Journal, industry knowledge

Scope to adjust product yields

Most refineries have some flexibility, without substantially changing crude slate, to adjust product yields. However, the ability to adjust the relative yields of gasoline, aviation fuel/kerosene and diesel/gas oil is fairly limited, and in most cases would be about 2-3% (on crude feed). Typically, all refineries minimise fuel oil and maximise yields of clean products such as gasoline and middle distillates at all times so a disruption to clean products would need to be addressed primarily with higher throughput at refineries.

There may be some scope in the UK for adjusting relative yields of aviation fuel and burning oil by diverting burning oil production to aviation fuel, given their molecular similarity and the ability to switch production between these two products, but this is likely to be limited. The UK produces over 90% of its burning oil needs domestically. There is a high degree of seasonality in the consumption of burning oil, with most of the annual consumption taking place in the winter months between October and March as it is used for heating. Refiners also tend to match the production of burning oil in winter to match demand rather than producing a constant amount throughout the year and stockpiling. Therefore, the ability to switch some of this production at UK refineries would be limited, as it would lead to unmet demand for burning oil.

UK refineries may have a limited ability to increase clean product yields using increased throughput of light sweet crude. However, there is also limited middle distillate conversion capability at UK refineries as they were mainly designed to produce gasoline and fuel oil. Although there may be spare capacity for distillation, middle distillate conversion capability may be running at or close to full capacity in which case increasing throughput would not deliver increases in middle distillates in proportion to average yields. As described in Section 2, new conversion or upgrading capacities are unlikely in the UK given the current market conditions and competition from new refineries overseas. The cost of making substantial changes to the yield structure on any UK refinery is likely to be high. The cost of changes to process higher sulphur or sour crudes are in the region of £260m to £440m, while additional hydrocracker capacity to increase middle distillate production would cost between £440m and £700m[42].

Scope for mothballing

When refining margins are negative, the usual first response for refineries is to move to minimum throughput. This allows oil companies to meet contractual supply agreements and keep operating plants in a safe and stable condition. Further, most fixed operating costs cannot quickly be reduced – these relate mostly to labour costs and during relatively short periods of poor refining margins, little can be done about reducing labour costs. However, if there is a more sustained period of poor refining margins, some refineries may be partially or fully shutdown, either by being mothballed or through decommissioning.

In previous periods of poor economic performance, some refineries have been fully or partially “mothballed”. Such a practice is not uncommon and aims to minimise costs or losses but to still preserve valuable process plant in a viable condition if required in the future. However, mothballing is only available as a short-term option. If a refinery is mothballed for an extended period (greater than 12 months) the inspection and re-commissioning process could take over 12 months, with corresponding costs. There is also likely to be some level of damage to the refinery, as plant and pipes may corrode over time. Furthermore, the skill losses following closure would require up to two years to recruit and train a full staff complement. In general, merchant refiners will not stop production for more than six weeks, and will keep the pipework warm and inspected during this period. In the longer term, the preferred option will be for owners to sell refineries or to close and decommission uneconomic refineries.

If a refinery is mothballed, the decision to sell or decommission will determine how much care is taken to keep the refinery in a ‘redeemable’ state. Under certain circumstances, parts of a refinery are removed for other refineries, meaning it is difficult to bring them back online in the future at short notice.

5.4 Export diversion

Crude

The UK currently exports around 41mt of crude oil annually, primarily to Europe and the United States. The decision to export is driven by commercial motivations, as crude is sold to consumers willing to pay the highest premium. The UK production is sold primarily on a spot basis, so there

[42] Industry sources. Based on estimates of €300m to €500m for changes to process sourer crudes and €500m to €700m for additional hydrocracker capacity.

are no constraints, other than ability to pay, to diverting exports in the event of a disruption to crude production.

Gasoline exports

The UK currently produces a surplus of gasoline, and this is forecast to continue under both the base and low refining capacity scenarios. The net surplus is currently 3.6mt per year, and will increase to 12.2mt by 2030 in the base scenario and to 6.4mt by 2030 in the low refining capacity scenario. In the event of an interruption to gasoline supply, the UK would be able to divert gasoline exports to offset the disruption. The UK refining industry is heavily dependent on the US market for placing its surplus gasoline production. US gasoline demand is set to continue to grow in the future, albeit at a far slower rate than historically due to the impact of efficiency measures[43]. However, we note that changes in the structure of US gasoline demand might have an impact on the ability of the UK to export surplus gasoline, and therefore on UK overall production.

Diesel/gas oil

The UK currently exports around 6mt of diesel/gas oil annually. However, a number of issues mean that the extent to which these exports might be diverted to offset lost domestic production or imports is limited.

- **Specification**. Some volumes of exported diesel/gas oil is of inadequate quality to meet UK specifications, and must be exported. In particular, this is the case for the 1mt of diesel/gas oil which is exported to African destinations, which in general accept diesel specifications with higher sulphur levels than in Europe. It is likely that refiners who are producing diesel/gas oil of lower grade are doing so because of plant limitations, and so not be able to be able to switch to producing higher grade diesel suitable for the domestic market.

- **Blendstocks**. The remaining diesel/gas oil exports are traded within Europe, including 1mt to Ireland. The majority of these exports are likely to be gas oil/diesel blendstocks. If there is insufficient tankage or refining capacity available in the UK for blending or further processing, product is often shipped to Rotterdam for blending. These blendstocks cannot be retailed in their current form.

- **Diesel vs gas oil**. The UK demands considerably higher volumes of diesel than gas oil (some 22mt in 2008 compared with 6mt of gas oil[44]). IEA data aggregate diesel and gas oil exports together, so it is not possible to determine the relative proportions of each. However, it is likely that more gas oil than diesel is exported, given the relatively low desulphurisation capacity of the UK refining industry. This suggests that there may be limited capacity to divert production that would otherwise have been exported to satisfy the primarily diesel domestic demand.

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[43] IEA, Medium-Term Oil Market Report, June 2009

[44] Wood Mackenzie, 2009

Aviation fuel

The UK has a structural shortage of aviation fuel, and currently imports 64% of demand. Imports are set to increase by around 5mt per year by 2030 in the base demand case, and by up to 7mt per year in the high demand case. Apart from around 1.9mt, of which approximately 1mt is exported annually to Ireland, there is little scope for diverting exports.

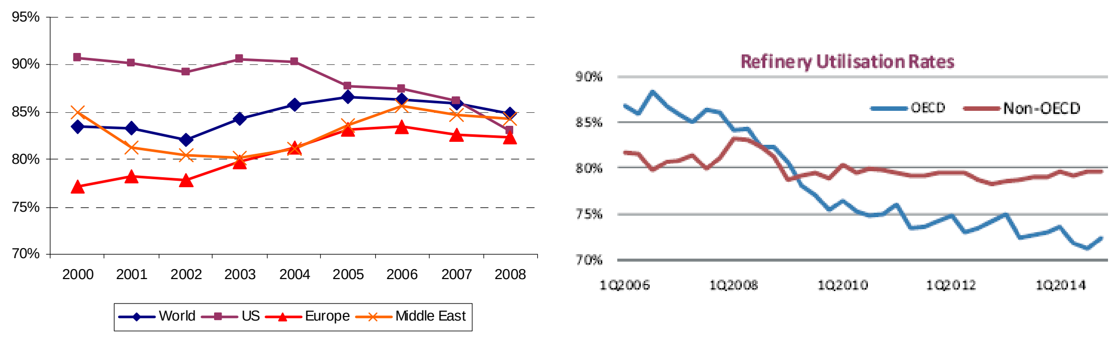
Burning oil

UK burning oil demand is almost entirely met by domestic supply, and little is exported. This is partly because European burning oil demand is concentrated in the UK and Ireland where burning oil, rather than heavier gas oil, is used for domestic heating. There is therefore very limited scope for diverting exports to offset a disruption to domestic supply.

5.5 Global spare refining capacity

Spare refining capacity can also help alleviate a supply disruption by allowing a higher throughput to compensate for the disruption, assuming the additional crude is available. The utilisation rate of a refinery measures the existing output in relation to the nameplate capacity, in most cases of the primary distillation of the refinery. Typically, “good” sustainable operation is perceived to be where refining is operating at around 90-95% of nameplate capacity as this is close to the technical maximum, allowing for a small amount of downtime for maintenance and minimising operating costs (per unit of crude processed).

Figure 32: Refining utilisation rates



Source: BP Statistical review, 2009 *Source: IEA Medium Term oil market report, June 2009*

On a global level, refinery utilisation will depend on demand for products and total installed refinery capacity in operation. Figure 32 shows that global refining utilisation peaked in 2006 and has declined since then. According to the IEA, refinery utilisation rates of OECD countries are expected to continue this decline over the next five years as refineries reduce their throughput. This change has been driven by the global recession and a fall in demand for oil products together with additional refining capacity coming online in 2008 and 2009. It also reflects different business models for NOC or state owned refineries which tend to be less commercially sensitive compared to those operated in OECD countries.

With more refining capacity expected to come on line over the next few years, (in particular in Asia and the Middle East), overall there is likely to be excess refining capacity in 2015. However, there are a number of key issues that may constrain the availability and scale of this spare capacity in response to particular supply disruptions.

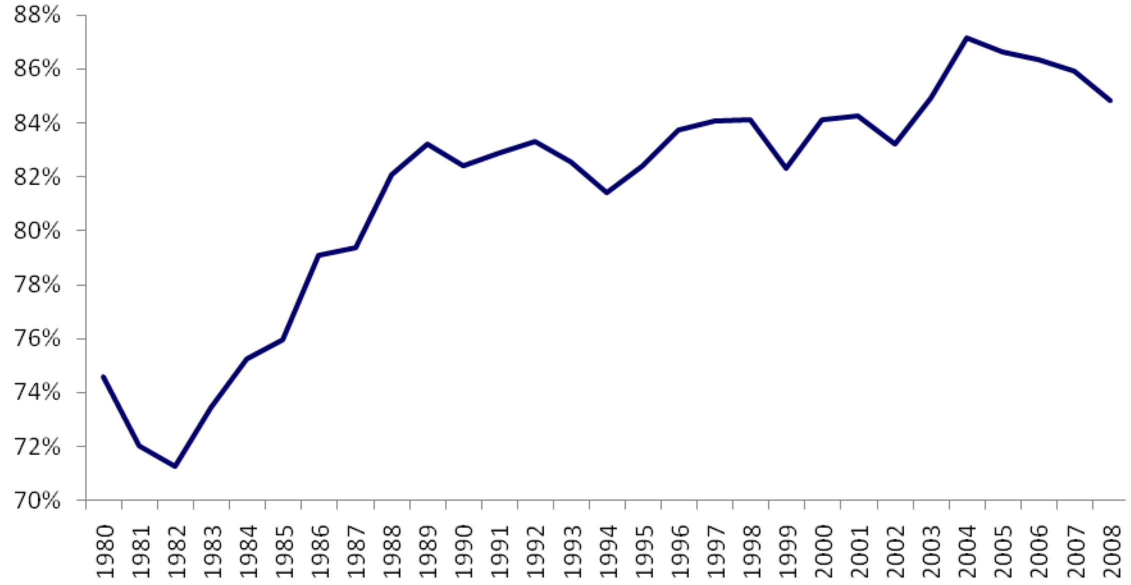
- **Extent of refinery closures**. Older and less efficient plants in Europe have seen their market share eroded by the new and more efficient investments in refining capacity in Asia. With excess capacity in North West Europe and a number of refineries operating with low margins, it is likely that a number of these will shut down over the next five years. The impact of this may be limited by political factors preventing closure and the high exit costs associated with decommissioning a refinery.

- **Growth in demand for products**. A significant increase in demand for products – especially for middle distillates - could mean that spare refining capacity may be limited for certain products. Some refineries may be able to increase yields of particular products. For example, some Middle Eastern refineries can increase the proportion of aviation kerosene in their yields from around 18% to 24-25% if there was a disruption. However, this would come at the expense of other products and so differences in relative prices would be needed to justify such changes.

- **Limited conversion/upgrading capacity**. Quoted refining capacities are based on primary distillation and are only an approximate indication of the true level of available capacity. Many refineries now reduce refining runs to “just fill” secondary conversion and upgrading units, leaving some spare capacity in the primary distillation units. Other refineries may have several primary distillation units and have chosen to mothball one or more units where these are in excess of what are required to fill the secondary conversion and upgrading units Therefore, if the disruption is for a particular product requiring secondary conversion or upgrading capacity, there may be limited spare capacity available to deal with a disruption.

- **Lower yields for incremental capacity**. In many cases, as refineries increase throughput to the limit of their primary distillation capacity, the incremental yields achieved are not the same as those achieved up to the level of operation at normal utilisation rates. This is because as incremental crude oil is processed, some of this cannot be further processed in conversion and upgrading units.

Figure 33: Estimated world refining utilisation rates (1980-2008)



Source: BP Statistical World Energy Review (2005 & 2009); Deloitte analysis

In summary, making projections of spare capacity in refining is challenging. Historic trends (Figure 33) may not persist going forward. Growth in trade for oil products has enabled many of the regional imbalances between product demand and refining capacity to be addressed. This trend allows low margin refineries to be closed and replaced by imports.

Nevertheless, many countries see refining as a strategic industry and may develop policies to ensure that domestic refineries continue to operate. There is also a number of oil producing countries that are seeking to diversify their economies away from oil production and see refining products for export markets as a key element of this strategy (See Box 2 below). For these reasons, the excess capacity in refining could continue in the future and help ease supply disruptions, assuming that markets and international trade are allowed to function during periods of supply interruption without political intervention.

Box 2: Why are other countries building up refining capacity?

A number of countries, notably in the Middle East and Asia are increasing their refining capacity, which is being supported by a number of key drivers:

- **Demand growth**. Expected future growth in demand for refined products as economies develop and oil consumption per capita increases.
- **Industrialisation**. To develop an industrial base and support economic growth and development of skilled employment.
- **Diversification**. Desire to diversify economy from dependence of crude oil production to higher value added services such as refined products. This is a key driver for increases in

capacity in the Middle East.

- **Government support**. Certain countries have attracted foreign investment by providing support to new refineries.

- **Economies of scale**. Larger, more complex refineries are being constructed given technological developments in refining and economies of scale (capacity for new refineries ranges from 400-600kbd, compared to existing UK refineries which average around 210kbd). With lower unit costs compared to older existing refineries, refined products can be exported to other markets (such as Europe) at competitive prices.

The UK is in a different situation to a number of these countries which limits the opportunities for new refining capacity to be built and in fact may lead to closures of UK refineries.

The UK has an existing refining capacity base that meets part of its demand for oil products. However, some of this refining capacity is ageing and less efficient compared to other European refineries and even more so when compared to new refineries being built in Asia.

UK refineries are operated by commercially sensitive companies that respond to changes in market prices by adjusting production levels. These companies operate in a global market and will locate capital investments to deliver the highest returns.

UK is seen as a mature market, with minimal growth in overall oil product demand, although there is a shift in the demand by types of products (reduction in gasoline and fuel oil demand but growth in diesel and aviation fuel).

The UK's planning and consent rules can deter new investment in the UK given the potential time that may be required to obtain planning permission for large scale industrial projects.

Number of oil terminals around the UK, proximity of UK to European refining capacity and the main European trading hub for refined products (Rotterdam) means that the UK is well located to import products by sea and to supply its inland regions.

5.6 Access to alternative product supplies

In the event of a disruption, a possible mitigation is to source additional refined products from international markets. There are a number of key drivers that will affect the ability to access alternative product supplies other than the levels of spare refining capacity discussed in Section 5.5.

The key driver of export flows and associated refinery utilisation is price signals. An interruption to refining capacity and resulting product shortage increases product prices and incentivises refiners to increase utilisation. The price effect resulting from an interruption depends crucially on the levels of spare refining capacity. Product market interruptions are less of a cause for concern and give rise to less price disruption when utilisation is in the region of 80% to 90% than when levels are above 90%, as they were in the mid 2000s. At times of tight capacity, the market's sensitivity to potential disruptions may drive excessive price reactions. Some of the market reactions to events when capacity was tight in the mid 2000s were extreme in relation to the magnitude of the event, and sharp upward movements were quickly reversed once the event was put into perspective[45]. For example, in September 2005 Hurricanes Katrina and Rita led to the loss of around 1.6mbd of refining capacity, when regional utilisation was already over 95%. The initial spike in gasoline prices was reversed within a few days once markets realised that supplies would still be adequate, helped by higher trade flows from western Europe[45] and emergency stock releases coordinated by the IEA.

Even with high levels of utilisation, some spare capacity is generally still available. When markets are tight, the spare refining capacity is usually of simple configuration with little capability to economically process heavier crude. This is because simple distillation capacity has a high yield of low-value products such as heavy fuel oil when processing heavier crude. However, given sufficient economic incentives – as would be the case during an interruption which prompted a severe price spike – the additional capacity would be incentivised to run as the high margins for the disrupted product would offset potential losses from increased production of low-value products.

Market liquidity has been facilitated by the increasing standardisation of product specifications. Twenty years ago diesel specifications varied even between different US states; now, there is increasingly one grade of diesel, namely the European/US 10ppm specification. Similarly, there is only one international grade of aviation fuel. New refinery investments which are geared towards export markets – such as Reliance's two new Jamnagar refineries – are configured to comply with European/US requirements. Although European/US requirements are still more stringent than in some emerging economies, particularly with regard to sulphur content, the trend is clearly towards further standardisation.

In addition, international trade in refined products has increased considerably in the last thirty years. Trade in refined products represented only 14% of production in the 1980s, but grew to 22% by 1990 and to around 25% in 2008[45]. Trade volumes have increased in order to offset regional imbalances and to take advantage of arbitrage opportunities. As an illustration, the sustained presence of gasoline shortfalls in the US – which are satisfied by exports of surplus gasoline from the UK and Europe – demonstrates that there are in general greater economic incentives to trade rather than to invest to match domestic market demand.[46]

Nevertheless, there are a number of factors that may limit access to alternative product supplies. Unique product specifications may limit access to markets. For example, there is only a small market for burning oil as most of Europe uses low sulphur gas oil for domestic heating. UK heating oil corresponds to what is known in Europe as industrial kerosene, for which there is only a small market. Currently, almost all of the UK demand for heating oil is met by UK production; however, there is a trend for UK refiners to switch away from burning oil production to concentrate on aviation fuel given the more stringent specification associated with heating kerosene and the

45 Purvin and Gerzt, "Study on oil refining and oil markets", 2008

46 That said, refineries that serve inland markets – such as those in central Europe – have better economic incentives to invest to match changing market demands as they are economically cut off from international trade due to the costs of transportation.

distribution costs. For example, Fawley has already stopped burning oil production. A lack of domestic production and the resulting need for increased imports could be problematic given the small international market in this product.

Furthermore, mothballed capacity might limit access to alternative product supplies. The time frames for increasing production in response to price signals are generally short. Refineries which are not operating to full capacity can rapidly increase production, in the space of a day or two. However, a longer lead time is required for refineries which have been temporarily shut down, generally in the order of 6 weeks or longer for refineries which have been mothballed.[47] The UK's close proximity to a large amount of refining capacity in Europe is an advantage in this case when seeking alternative volumes of refined product, as these are able to supply additional product within short timeframes.

There may also be political intervention which may limit the liquidity and availability of products from international markets. This would be a more extreme case where international markets do not function normally – for example, following a catastrophic interruption – and product is not available at any price.

5.7 Shipping

The potential of shipping to reduce or enhance resilience depends on capacity. In the event of a supply disruption, more tanker capacity may be required if alternative sources require long-haul shipping. Similarly, if refining capacity that was previously supplying a domestic market is interrupted, additional tanker capacity may be needed to import alternative product from other sources.

Capacity in the shipping market is highly correlated with crude and product demand. In particular, it is driven by demand for Middle Eastern production, which is associated with long-haul tanker requirements. The growing demand for oil and oil products experienced until mid-2008 led to increased investment in tankers. Much of the new tanker tonnage is being delivered in the next few years, given the long lead times in shipbuilding. It is likely that there will be a large surplus in tankers by 2015.

Developments in global oil and oil product demands will determine the shipping capacity after 2015. However, it is unlikely that shipping will act as an isolated constraint on the ability to access crude or product supplies. Given the relationship between shipping capacity and demand, it is more likely that bottlenecks in either crude or refining production will act to constrain access before shipping capacity does.

We note that sailing speeds provide some built-in flexibility in the shipping market. In times of constrained supply, tankers can sail at up to 15.5 knots, while in a weaker market they will tend to do around 12 knots. This reduces sailing time in the event of a supply disruption, when crude or product needs to be sourced from potentially more distant destinations.

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47 The timeframe to bring a mothballed refinery back into production depends on the mothballing process. Longer time frames are required in some cases, for example if refinery parts have been removed to be used in other refineries.

5.8 UK handling capacity

Given the UK's position as an island nation with a developed oil distribution infrastructure and downstream sector, the UK's resilience is enhanced by the number of import points around the country. UK refineries contribute to this diversity in import points both in terms of their number, location and handling capacity for a number of products.

A possible benefit of the existing infrastructure at UK refineries is the potential option, if necessary, to run the facility as a product rather than crude import facility. Refineries tend to have high levels of connectivity between jetties and tank farms, and so it might feasible to use the sea terminals to unload product rather than crude in the event of a crude interruption and transfer this to the normal product storage tanks for distribution[48]. That said, there are constraints which may limit the ability temporarily to convert refineries to product import terminals. Product ships tend to be much smaller than crude tankers, and the discharge facilities at the jetty may be of the wrong size to unload the product. Furthermore, flushing pipes to clean out the crude and avoid product contamination is onerous and time-consuming.

Handling capacity may be constrained by ship size. In particular, import facilities attached to refineries tend to accept larger ship sizes than some independent import terminals. Options do exist to circumvent this issue, such as bulk-breaking large tankers in-port elsewhere or ship-to-ship transfers, but these incur time delays.

5.9 Utilisation of inventory and stocks

Companies operating in the UK market keep a certain level of working stocks as part of their day-to-day business activities. These stocks are normally required to smooth out differences in delivery and throughput rates, to be used for production/blending of products and to cover potential delays or operational problems. The actual volumes differ between companies but, as a minimum, companies will typically hold between six and 16 days worth of stocks based on the average volumes supplied to the UK.

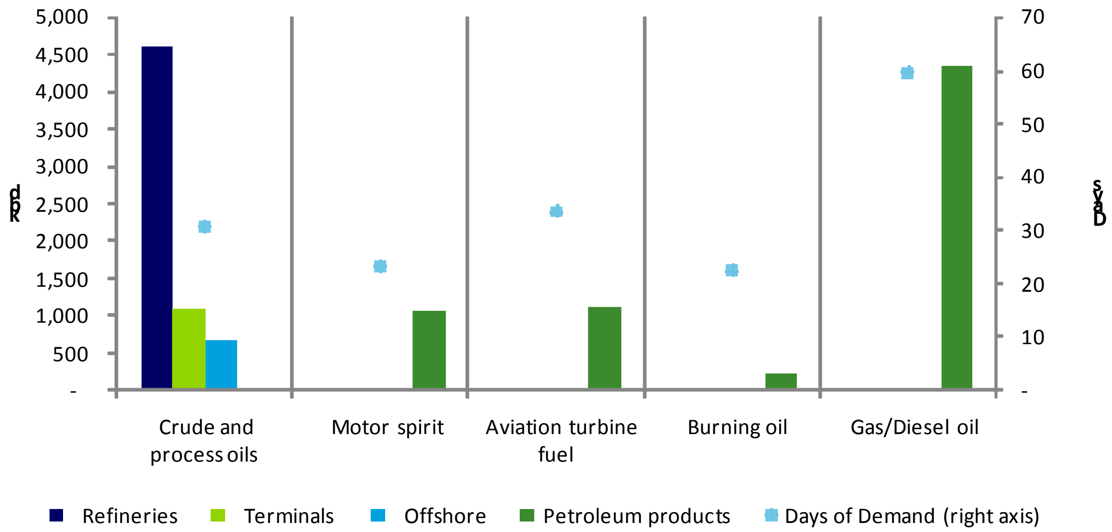
In addition to working stocks, UK companies are required to hold additional oil stocks as part of the UK's requirements for holding emergency stocks under IEA and EU membership. The IEA has a number of emergency response mechanisms to offset the impacts of short-term oil supply disruptions, with stockdraw being the most powerful of these. In the event of a major international disruption of oil supplies, the IEA co-ordinates a collective release of stocks from its 26 member countries. The co-ordinated response carried out after Hurricane Katrina hit the Gulf of Mexico in August 2005 demonstrates the ability of the IEA to respond effectively and decisively to an oil supply shortfall.

48 Typically, deep sea terminals/jetties can be used for unloading different types of products. In particular, crude can be substituted by finished product if pipeline seals are compatible and can cope with the variation in product characteristics, such as gas content; flammability, and viscosity. In order to replace crude import with finished product import, valves need to be closed/opened (the pipe work to link the deep sea terminals to the tank farm is normally in place), and pipes need to be 'flushed'.

As an oil producer, the UK has the benefit of a derogation of 25% of the EU's compulsory stocking obligation ("**CSO**") to 67.5 days of consumption, which to date has effectively superseded the IEA requirement. However, as the UK's oil production declines, the IEA obligation will increase.

The UK currently meets its obligation by placing compulsory requirements on oil companies operating in the UK. Currently, refiners in the UK are required to hold 67.5 days of stocks in products supplied to the market, while non-refiners/importers are required to hold 58 days of stocks. A large proportion of these stocks are held in the UK, either as finished products, or as crude oil and feedstocks to be refined. Companies are also able to have agreements with certain countries holding stocks on their behalf where a bilateral stocking agreement exists between the UK and the relevant country.[49] Figure 34 shows the UK stocks at the end of 2008 by product and as a percentage of 2008 demand.

Figure 34: UK stocks of crude and selected oil products (2008 year end)



Source: DECC, Digest of UK Energy Statistics

In the event of a major disruption, the IEA will coordinate a response from its member countries and agree levels of stock release for each country. It will be then up to each country to implement the stock drawdown in line with their emergency procedures. The UK response to a supply disruption is coordinated by DECC and takes the form of a stock drawdown by reducing the obligation of companies operating in the UK. The effect of reducing the obligation is to enable companies to release their stocks to the market and minimise the impact of a supply disruption.

The majority of stocks are held at refineries or import terminals. UK independent storage capacity is in excess of 5.5m tonnes, almost all of which is for refined product. Refineries are estimated to have in excess of 5.7m tonnes of storage capacity for crude oil alone, with additional capacity for

[49] The UK has formal bilateral agreements with Denmark, Ireland, Sweden and the Netherlands and informal ones with France and Belgium.

refined products. The location of the stocks means that they can generally be fed into the market using the existing supply chain when required. However, a number of issues could constrain the use of stocks in the event of a supply disruption.

- **Location of stocks relative to disruption**. Stocks may not be located at the point where they are needed for a particular disruption as they are normally kept at refineries or import terminals. This may limit the use of stocks to a regional supply disruption.
- **Availability of product stocks**. In some cases a large proportion of stocks are held as crude oil for processing rather than as finished stocks, as it is typically less costly to store crude than products. In the case of a disruption to a UK refinery, there may be limited supplies of refined products available for use. Furthermore, an interruption to product imports is likely to require stocks held in the form of product rather than as crude.
- **Time to arrive in market**. For certain products, there may be a considerable volume of product stored overseas. If the disruption were to affect transit, these products may take longer to reach the UK or may not be available at all.
- **Capacity constraints in the supply chain**. Stocks are likely to use the same infrastructure and supply chain in the UK. There may be specific bottlenecks or constraints in capacity of the supply chain (such as pipelines) which may limit the ability for products held in stocks to be supplied to the areas required.

5.10 Demand rationing

Demand for oil products is slow to respond to oil price signals. There are few substitutes for oil in the short-term, and so changes in demand in response to higher prices tend to manifest themselves through long-term changes which take months or years to emerge. These include modal shifts (for example, from cars to trains) or changes in investment choices, such as buying more fuel-efficient cars or investing in less oil-intensive forms of production. This is in contrast to some other energy sources. As this winter has shown, some mechanisms exist for demand management in gas in response to constraints in supply, such as interruptible contracts. There are few such mechanisms in oil for many products.

Furthermore, the response of oil product demand to price signals is diluted in the UK by taxes. The application of taxes on oil products means that a change in the product price leads to a less than proportional change in final price.

Studies into the price elasticity of demand have confirmed that elasticity values are small. Short - run demand elasticity estimates for crude oil in OECD countries are in the order of -0.1 to -0.3[50]. Moreover, demand elasticity has been falling over time. This may be due to the falling share of oil costs in total expenditures, or to the proportional increase in oil used for transportation, where there are fewer substitution possibilities than in non-transportation uses of oil.

[50] OECD, “Recent oil price movements: forces and policy issues”. Economics Department Working Papers, NO 737 December 2009. Available at http://www.olis.oecd.org/olis/2009doc.nsf/LinkTo/NT000088AA/$FILE/JT03275799.PDF

Nevertheless, demand does respond to sustained price signals, although the effects may take some time to be seen due to short-term rigidities. For example, US gasoline demand began to fall from 2006 in response to high prices, well before the onset of the global downturn. The decrease in demand was due to shifts in consumer behaviour, including driving less and switching to more efficient vehicles.

However, the oil industry is generally reluctant to use pricing as a mechanism to control demand following localised interruptions such as a domestic refinery outage[51]. This approach to rationing demand is often misinterpreted as profiteering and unlikely to be acceptable. Fuel purchases are not for the most part discretionary spending and thus a price hike to limit usage is often not considered an option.

When shortages in fuel supply can be anticipated, voluntary rationing or demand calming measures can be effective; for example, in relation to the industrial action at Grangemouth in April 2008. In this case, decisions by some filling station managers to limit fuel usage proved effective in constraining demand for a limited period to cover the disruption from the two day strike. Maximum sales per individual at some filling stations were largely accepted and helped to prevent precautionary filling of tanks.

In more severe supply disruptions, greater control over rationing and demand is likely to be required. The National Emergency Plan – Fuel (**"NEP-F"**) is the method used to allocate fuel in times of severe shortage. This plan requires the Government to take emergency powers and will therefore only be used in extreme circumstances. Its objective is to direct fuel to those individuals and organisations that are critical to maintaining essential services and infrastructure. There are several elements to the plan defined by the DECC.

- The **Maximum Purchase Scheme** limits the general public to 15 litres of fuel per visit (though this is variable).
- The **Designated Filling Stations** ("**DFS**") scheme provides priority access to road transport fuels for defined customers requiring them for a priority use. DECC implements the scheme, designating a number of filling stations for the provision of fuel for Emergency Service Scheme, Utilities Fuel Scheme and Temporary Logo Scheme priority use only.
- The **Commercial Scheme** prioritises diesel supply to commercial filling stations and truck stops.
- Under the **Emergency Services Scheme**, fuel is prioritised to Designated Filling Stations which would allow unlimited fuel to blue light emergency vehicles.
- Under the **Utilities Fuel Scheme**, fuel would be prioritised to Designated Filling Stations for use by logoed vehicles in the delivery of pre-identified essential services.

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[51] We note that different retail prices do prevail across the UK, which reflect differences in distribution costs. However, localised price changes beyond these accepted levels of variation are not seen as publicly acceptable.

- The **Bulk Distribution Scheme** enables oil companies and distributors to prioritise fuel products to supply retail filling stations, truck stops, depots and commercial storage sites.

- Under the **Mutual Aid Scheme**, DECC has encouraged organisations to develop voluntary mutual aid arrangements to support the delivery of essential services.

6 Analysis of scenario impacts

This section examines in more detail each of the interruption scenarios set out in Section 4.2, and assesses the extent to which the mitigating actions outlined in the previous section are able to compensate for the supply interruption. The discussion of each interruption scenario concludes with a summary table that provides an indicative quantification of the net impact of the interruption on the UK, and how this differs under the assumption of base or low refining capacity.

Our analysis relies on a number of simplifying assumptions, including the following.

- We assume that interruptions occur when all existing UK refining capacity is fully operational (in other words, there are no scheduled maintenance outages which have already reduced refining capacity).
- We have not taken account of seasonality, and assume that annual demand, import and domestic production figures can be averaged across the year.

For ease of reference, we first present a summary table containing the details of each of the interruption scenarios set out in Section 4.2.

Table 18: Summary of interruption scenarios

Interruption	Total volumes disrupted			Disruption duration (days)	Probability
	2008	2015	2030		
Norwegian crude exports	660mbd	510mbd	330mbd	180	1 in 30 years
Russian crude exports	1mbd	1mbd	1.3mbd	21	1 in 10 years
Indian aviation fuel exports	6.8kt/day	6.8kt/day	6.8kt/day	180	1 in 10 years
Saudi crude exports	1mbd	1mbd	1mbd	180	1 in 5 years
Rotterdam diesel/gas oil exports	29kt/day	29kt/day	29kt/day	21	1 in 10 years
UK domestic refinery	266kbd processing capacity			21	1 in 10 years
UK aviation fuel import terminal	3.3kt/day	3.3kt/day	3.3kt/day	21	1 in 10 years

6.1 Norwegian crude imports

Initial disruption

An incident affecting the Norpipe pipeline will disrupt flows of light, sweet Norwegian crude to the UK[52]. Our scenario assumes that some 80% of UK imports from Norway are routed through the pipeline. This suggests that some half a million barrels a day of crude exports to the UK are disrupted in 2008, which represents a third of UK domestic refining production. The scale of this interruption would be the same under high case UK demand assumptions, as additional demand requirements would be met by additional product imports rather than by increased demand for crude imports.

The table below shows the volumes which are assumed to be disrupted in this scenario, as well as the corresponding volumes of product which would have been produced from the interrupted crude. The percentage of demand which these volumes represent varies by product, depending on the relative levels of imports and exports[53].

Table 19: Interrupted Norwegian crude and associated product volumes – Base refining capacity

	2008		2015		2030	
Total disruption to Norway supply(kbd)	660		510		330	
Interruption to UK crude imports from Norway (kbd)	500		400		200	
% of UK domestic production affected by interruption	33%		27%		12%	
Interruption to refined products	**Kt/day**	**% of demand**	**Kt/day**	**% of demand**	**Kt/day**	**% of demand**
Gasoline	18.3	40%	14.6	43%	7.3	29%
Diesel/Gas oil	24.2	32%	19.4	23%	9.7	12%
Aviation fuel	5.9	17%	4.7	12%	2.4	5%
Burning oil	2.8	27%	2.2	27%	1.1	17%

Note: the interruption to refined products following the original crude interruption is calculated as the volumes of refined product which would have been produced domestically from the interrupted volume of crude.

52 Although alternative offtake arrangements are possible to transport oil from the fields tied in to the Norpipe pipeline – for example, a temporary offshore loading system such as a single buoy mooring system – these would take several months to be developed and so are not feasible within the time frame of this scenario.

53 For example, the disruption to gasoline production is equivalent to 33% of domestic production but 40% of demand, since a relatively large proportion of domestic production is exported.

The direct impact of this scenario is reduced under the assumption of low refining capacity, as the UK becomes less exposed to an interruption in crude supplies. However, the dependence of the UK on light, sweet crude means that the UK will still be vulnerable to a disruption in Norwegian crude. The low refining capacity scenario assumes that UK refining capacity is reduced by 27%. Simplistically, this will lead to crude import requirements reducing by 27% and thereby the interrupted volumes reducing from 500kbd to around 365kbd. The actual effect will depend on the pattern of imports. If the closure of UK refineries means that there is additional Norwegian crude available on the market, remaining refiners may chose to replace North and West African imports with Norwegian imports given the geographic proximity of Norwegian production.

The impact of this interruption would be felt immediately at the Teesside reception terminal, as pipeline flows would cease with the pump failure. However, crude is then loaded onto tankers and shipped to other UK terminals. UK refiners would therefore have around 4.5 to 5.5 days warning of the disruption.

A disruption to Norpipe will also affect Norwegian exports to other destinations. Apart from the UK, Norwegian crude is imported primarily by France, Germany, and Canada. However, since we have assumed the majority of Norwegian exports through the pipeline are destined for the UK, this scenario affects only around 2% of each of France, Germany and Canada's crude imports.

Under the assumption of lower refining capacity in the UK, Norwegian exports to European and North American destinations are likely to increase due to reduced demand from the UK. The UK will also be importing more product due to the reduction in domestic production, and some of this increase – particularly for gasoline and to a more limited extent diesel/gas oil – may come from Europe, although we have noted in Section 2.2 that increased product imports are more likely to come from the Middle East, Asia and possibly North America. These two aspects mean the UK may be impacted by the displacement of the interruption to European product markets under the assumption of lower UK refining capacity. However, European refiners have far more diverse sources of crude imports than the UK, with its dependence on North Sea crude. Even assuming that the interruption to the UK is only 365kbd, the remaining interrupted volumes will disrupt less than 5% of the crude imports of any European importer of Norwegian crude[54].

Measures to mitigate interruption

Alternative crude imports

Following an interruption to Norwegian North Sea production, refiners would initially seek to replace the lost supply with crude of the same grade, ideally from other North Sea production. The price of these immediate alternatives would be bid up, and ability to pay would determine access to these alternatives.

Given some available spare capacity in Saudi Arabia, additional supply is likely to be made available to the market through Saudi Aramco's existing customers. However, the primarily sweet slate of UK refiners means that alternative imports to replace the interrupted Norwegian crude

[54] This is with the exception of Ireland and Denmark, neither of which export more than negligible volumes of refined product to the UK.

would need to be sourced from producers of light, sweet crude. The immediately available Saudi spare capacity would be heavy, sour crude, and so of limited use to the UK. However, in the event of a major interruption to light sweet crude supplies, it would be expected that that the price differential between sweet and sour crude would widen. This would encourage refiners who were able to run sourer crudes to do so, thereby freeing up light sweet supplies for UK refiners. This process would occur over three to six weeks, as refiners re-ran their linear programme to determine the optimal feedstock as described in Section 5.2.

Generally speaking, light sweet crude is available from the North Sea, North Africa, West Africa, and the Caspian, all regions from where production is generally sold on a spot basis. West African and Caspian production is set to increase between now and 2030. In particular, alternative crude is available from the UKCS. The UK currently exports 41mt – around 0.8mbd – of crude each year, around 63% of current production. Although exports are predicted to decline to 0.6mbd in 2015 and 0.3mbd in 2030, these volumes are still sufficient to cover the expected lost production in this scenario in 2015 and 2030. In the event of a supply interruption, the UK may be able to divert these exports to domestic production, given sufficient willingness to pay. The UK would have a cost advantage over other consumers given relatively low transport costs and therefore have the ability to pay a premium.

The time required for alternative imports to be delivered depends on the source. North Sea crude could be delivered in similar timescales to the interrupted Norwegian imports from Teesside. Including loading and unloading time[55], North African crude could be delivered in around 12 days while cargoes from the Caspian and West Africa would require 14 and 16 days delivery time, respectively. This suggests that UK refiners could be faced with a delay of up to 10 days before a replacement cargo could be unloaded. However, cargoes could be sourced far sooner if tankers that are already on route are diverted to the UK**.**

Under the assumption of lower UK refining capacity, reduced volumes of alternative crude would need to be sourced. This would increase the resilience of the UK to an interruption of this nature. The need to source alternative crude would be displaced to European importers of the interrupted Norwegian volumes, which would have a knock-on effect on UK product imports from European sources. However, European crude slates are far less sweet than UK average slates, with only 45% of 2008 crude imports being from regions which are broadly defined as producing sweeter crudes[56]. This suggests that European refiners would have a greater ability to substitute away from sweet crude to the more freely availably sourer crudes.

Temporary exemption from environmental requirements

Without the appropriate investment in refining capacity, some UK refiners may not be able to process heavy, sour crudes sufficiently to remove sulphur and other impurities in order to meet

[55] We do not include booking time in these timescales, as this will vary depending on the specific supplier and the urgency with which the replacement shipment is booked. The time for transit, loading and unloading represents the minimum possible time for a shipment to arrive.

[56] The calculation of European slates is based on OECD Europe imports. Countries considered to produce sweeter crudes are North Africa, North Sea, West Africa and the Caspian.

product specification standards. Furthermore, the processing of sour crudes without the correct equipment can result in levels of emissions which breach environmental requirements.

A shortage of light sweet crude after an interruption to Norwegian exports might be mitigated by relaxing product specifications and emissions standards and allowing UK refiners to process heavier crude. However, the extent to which specifications can be temporarily relaxed is constrained by end user equipment being no longer suited to high sulphur products. For example, catalytic converters in diesel cars will sustain permanent damage from using high sulphur diesel fuel. Additionally, relaxation of the 'soft' emissions standards might not be sufficient to allow processing of sourer feedstock, and may be politically infeasible given emission reduction targets. Furthermore, EC sanction would be required for any derogation on product specifications or emission requirements, and this may not be available.

It is therefore not clear the extent to which temporary exemption from environmental requirements can mitigate a disruption to light, sweet crude supplies.

Reduction in product exports

As outlined in Section 2.2, the UK currently produces a net excess of gasoline. This is set to increase by 2030 (subject to the structure of US gasoline demand), given the fall in domestic gasoline demand. By diverting gasoline production which would otherwise have been exported, UK refiners could replace all of the lost production in 2015 and 2030, and around half in 2008, under assumptions of both base and low refining capacity.

The ability to reduce other product imports is far more constrained. This is because little aviation fuel/kerosene is exported, except to Ireland, and diesel/gasoline exports may be of incorrect quality, as discussed in Section 5.4.

Alternative product imports

As an alternative to sourcing alternative supplies of crude, the UK could source additional product supplies to offset the production lost from UK refiners. This may offer additional resilience if the UK is unable to access sufficient light sweet crude, as it can import additional product from refiners who are able to process the increased supply of heavy sour crude from Saudi Arabia.

If alternative product imports are available, then the key constraint is the capacity of UK import terminals to increase the volume of imports. Table 20 below shows the proportional increase in product import volumes if product imports were to entirely replace the interrupted crude supplies. With the exception of aviation fuel, fully replacing lost domestic production with product imports would require a doubling or even a tripling of product imports[57], which is unlikely to be feasible.

[57] This proportion would be reduced under the assumption of less refining capacity, as the normal, non-interruption level of product imports would be higher. However, we are not able to determine exact proportions as we are only able to calculate net product imports based on the balance between domestic production and demand, and actual import levels tend to be higher due to product exports.

Table 20: Required increase in imports without domestic production

Product	2008 imports (daily average)	% increase resulting from replacement product imports
Gasoline	7.8	235%
Diesel/Gas oil	20.9	116%
Aviation fuel	22.3	36%

Source: IEA

That said, however, replacement product would only need to be imported if domestic refineries were unable to source the required grade of crude. In this case, there would be a considerable or even full reduction in refinery operations[58]. In the event of a shortage of crude supplies and a reduction in refinery utilisation, refineries may, to a certain limited extent, be able to use their facilities to import product and then distribute it via their usual mechanisms. Moreover, little – if any – gasoline at least would need to be imported, given the potential to divert gasoline exports.

Under the assumption of reduced refining capacity, the UK would need to source less alternative crude and so would be less likely to need to source alternative product imports to replace lost domestic production. There would also be less handling capacity constraints. However, at the same time the UK may need to replace an increased volume of product imports from Europe, if European refiners affected by the Norwegian disruption were unable to source alternative crude supplies. We have noted though already that European refiners tend to have a greater ability to substitute away from sweet crude to the more freely availably sourer crudes and so would have less difficulty in sourcing alternative crude.

Utilisation of inventory and stock

Even if it were not possible to source alternative supplies of crude or product imports, stock levels are in general sufficient to last for the duration of a six month crude import disruption. Even in 2008, when the volumes disrupted by this scenario are the highest, CSO stocks of diesel/gas oil, aviation fuel and burning oil[59] are sufficient to replace production for the duration of the six month period. The exception is for gasoline, where stocks are sufficient for all but eight days equivalent of demand in 2008. However, we have noted earlier that a surplus of gasoline is produced, which is then exported.

58 As a rule of thumb, refineries can reduce utilisation to approximately 65% before becoming unstable.

59 These are held in the form of both crude and products.

Table 21: Ability of CSO stocks to mitigate disruption to Norwegian imports

Product	Total cumulative volume of 6 month disruption (kt, 2008)		Shortfall in CSO product stocks (kt, 2008)	
	Base	Low refining	Base	Low refining
Gasoline	3,334	2,777	-388	169
Diesel/Gas oil	4,425	3,686	2,406	3,145
Aviation fuel	1,074	895	651	830
Burning oil	507	423	8	92

Source: DECC, Digest of UK Energy Statistics
Note: Shortfall in CSO product stocks is calculated as the current stock levels less cumulative interrupted volume. A negative value means that stocks are unable to cover the full volume of the interruption.

Summary of net impact of interruption

An interruption to Norwegian crude exports of around 660kbd will have an immediate global market impact, with the crude shortage relative to pre-interruption supply levels being reflected in price increases. Assuming historic elasticity values, an estimated price rise of around 30% to $93/bbl will follow the disruption (from a pre-inflation price of $72/bbl). The price increase would result in a demand response, as demand adjusts in line with the new prices. Access to scarce grades of crude will therefore be rationed across the global market by the increased price for one to two months until markets are able to rebalance. For the UK, this demand adjustment would be in region of 12kbd[60].

Price differentials between disrupted and other grades of crude would then lead to the market rebalancing, with additional spare capacity released by Saudi and refiners substituting away from higher quality grades where possible. This is likely to free up sufficient supplies of light sweet crude for UK refiners. This rebalancing would lead to a partial reversal of the initial price spike, with the extent of this determined by volumes of spare Saudi production and the degree to which refiners are able to rebalance their slates in favour of sourer grades.

We note that if there are rigidities which prevent the market response described above, other alternatives are available to prevent a physical supply interruption. Exports of UKCS crude could be diverted, which would be sufficient to cover the full volume of the initial interruption. However, these additional volumes could only be obtained at the market price, meaning that the price rationing effect would still occur until the market rebalanced. Other options include diversion of product exports. This would almost entirely cover the interruption to gasoline, although this mitigation would be insufficient for diesel/gas oil and aviation fuel. Finally, CSO stocks would be adequate to cover any shortfall, with sufficient stocks to offset the entire interruption except for gasoline in 2008. In general, use of CSO stocks might be needed even with a market response due to time lags in the delivery chain and transportation time from alternative source regions.

[60] This assumes that oil price elasticity of demand in the UK is similar to the international oil price elasticity estimates we have used.

Taken together, these mitigating measures mean that there will be no physical interruption in supply to the UK resulting from the original interruption, although there will be a price effect.

The direct impact of this scenario is reduced under the assumption of low refining capacity, since imports from Norway are reduced. However, the UK would still incur the increase in the crude market price as this would feed through to product import prices.

We summarise the effect of the various mitigation options in the table below. These have been assessed on their ability to compensate for the interruption on a stand-alone basis, rather than when used in conjunction with each other.

Table 22: Summary of the impact of mitigation measures for Norwegian crude disruption

Year	Scale	Duration of disruption	Impact on UK	
			Base refining	Low refining
2008	660kbd	180 days *(Time to impact: 4.5 – 5.5 days)*	500 kbd *33% of crude demand*	*365 kbd* *24% of crude demand*
2015	510kpd		400 kbd *28% of crude demand*	*292 kbd* *28% of crude demand*
2030	330kpd		200 kbd *14% of crude demand*	*146 kbd* *14% of crude demand*

Measures to mitigate interruption

Mitigation	Issues	Time	UK interruption	
			Base refining	Low refining
Sour heavy crude imports	• Very limited UK capability to replace light sweet feedstock with heavy sour	• Approx 2 weeks to increase production + 21 days transit (from Saudi via Suez)	No mitigating effect on interruption	
Sweet light crude imports	• Available initially only at a high price premium • Market rebalancing subject to other refiners switching to sourer slates and freeing up sweet crude supplies, and additional sour crude spare capacity	• 5 – 16 days to attract alternative imports • 1 – 2 months for full market rebalancing	100% interruption for 5 – 16 days (at pre-shock demand levels)	
Increased domestic production	• Not applicable (assumed maximised processing facilities for heavy sour crude)			
Diversion of crude exports	• 800kbd exported from UKCS currently. Assumed to be 600kbd or more in 2015 and 300 kbd in 2030 • Primarily spot basis so no contractual obligation • Price premium involved	• Immediate	No interruption	No interruption
Diversion of product exports	• Substantial exports of gasoline	• Immediate	• No gasoline interruption in 2015/30, 8.5kt pd interruption in 2008	• No gasoline interruption in 2015/30, 3.5kt pd interruption in 2008
	• 3kt/day of aviation fuel exports to Ireland and further 2.2kt/day unspecified exports		• Aviation fuel interruption of 3.6kt/day (2008), 2.4kt/day (2015) and 0.1kt/day (2030) if divert all but Irish exports	• Aviation fuel interruption of 4.2kt/day (2008), 3.7kt/day (2015) and 0.7kt/day (2030) if divert all but Irish exports
	• Very limited ability to divert diesel/gas oil exports due to quality issues		• Up to 24.2kt/day diesel/gas oil interruption (32% of demand)	• Up to 17.7kt/day diesel/gas oil interruption (23% of demand)

Product imports	• From refiners able to process sour crude • Potential UK handling capacity constraints • Subject to spare refining capacity	• 5 to 40 days, depending on source	Full interruption for 5 – 40 days	Full interruption for 5 – 40 days
Stocks	• Able to use both crude and product stocks	• Immediate	Maximum interruption of 390kt gasoline interruption (8 days demand)	No interruption
Immediate price impact following interruption				
30% price increase to $93/bbl from $72/bbl				

Source: Deloitte analysis

6.2 Russian federation crude exports

Initial disruption

Broadly speaking, Russia exports crude and product via four main channels: the Druzhba pipeline network to Central and Western Europe; Black Sea ports such as Novorossiyst; Baltic ports such as Primorsk; and Barents Sea ports such as Murmansk. These routes are shown in Figure 35 below.

Figure 35: Primary Russian oil and gas pipelines to Europe

Source: EIA

In the event of an interruption to exports from Primorsk, the alternative delivery routes could facilitate additional exports from Gdansk and Rostock and from the Black Sea ports in Southern Europe. Such supply routes have been used to compensate for other interrupted delivery routes in the past. In particular, the expansion of the Baltic Pipeline System (work on BPS-2 officially began in June 2009) will divert oil from the Druzhba pipeline system, which will transport diminishing volumes and so have available capacity in the event of a disruption[61]. Extra volumes diverted through the Druzhba can be exported via the Polish Naftport terminal at Gdansk. This has a capacity of 23m tonnes, through which Russia currently exports 4m tonnes. Additional spare capacity could also be provided by the pipeline links to the Baltic ports of Ventspils and Butinge. In particular, the LatRosTrans pipeline that feeds into Ventspils has a capacity of approximately 0.3mbd, and is now currently 50% utilised[62] due to the removal of Russian exports through this route. Furthermore the cost premium associated with utilising Russia's dense rail network may become viable in the event of a disruption and so supplement the current pipeline capacity. Exports to Western Europe via rail have been falling in the last five years as the cost advantage of pipelines

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[61] Reed, A. (2009). "Coming from Russia: more crude, lighter and sweeter". Oil and Gas Journal, August 2009

[62] http://www.latrostrans.lv/?language=eng

has driven a shift towards pipeline transit[63]. This suggests that spare rail export infrastructure will exist in the event of a disruption to pipeline routes.

Whilst alternative export routes are not likely to fully compensate for the total loss of exports from Primorsk, we assume that the volume of the disruption could be reduced at least to 1mbd by diverting exports through the following alternative channels.

Crude market impact

The UK's supply from Russia is small compared to the total export level, at around 130kpd in 2008. The majority of UK imports from Russia are shipped from Primorsk, and so an interruption to the port would be likely to affect all UK imports. Net interrupted crude volumes (assuming that a proportional volume of exports to the UK can be diverted through the alternative channels discussed above) and the associated refined volumes are shown in the table below. We have assumed that net direct interrupted volumes remain constant over time, as without additional investment it is unlikely that UK refiners will increase their demand for the Urals blend. Moreover, the scale of this interruption would again be the same under high case UK demand assumptions, as additional demand requirements would be met by additional product imports rather than by increased demand for crude imports.

Table 23: Interrupted Russian crude and associated product – base refining capacity

	2008		2015		2030	
Net total interruption	1mbd		1mbd		1.5mbd	
Net interruption to UK imports from Russia (kbd)	90		90		90	
% of domestic production	6%		6%		6%	
Interruption to refined products	**Kt/day**	**% of demand**	**Kt/day**	**% of demand**	**Kt/day**	**% of demand**
Gasoline	3.3	7%	3.3	10%	3.3	13%
Diesel/Gas oil	4.4	6%	4.4	5%	4.4	6%
Aviation fuel	1.1	3%	1.1	3%	1.1	2%
Burning oil	0.5	5%	0.5	6%	0.5	8%

Source: IEA; Deloitte analysis

The direct impact of this scenario is slightly reduced under the assumption of low refining capacity, as the volume of Russian crude imports is reduced. This is fairly marginal given the low current demand for non-North Sea crude. Assuming demand for Russian crude decreases in proportion to the reduction in refining capacity, the volumes interrupted in the low refining case scenario in 2008 are approximately 65kbd rather than 90kbd.

Product market impact

[63] http://www.analyst-network.com/article.php?art_id=1634

Russia is a major and geographically close supplier to Europe, and an interruption to Primorsk will have a significant effect on a number of other North-West European countries, including Belgium, Finland, France, the Netherlands and Sweden. This is likely to have a second-round effect on the UK, as the Netherlands and Sweden are also exporters of refined product to the UK. Table 24 below shows the estimated interrupted volumes to each of the key export destinations, and the share of crude imports that this interruption represents.

Table 24 also shows the impact of the product market disruption on the UK. At a minimum, this is the proportional impact on the volumes of diesel/gas oil and gasoline[64] imported by the UK from each of these European destinations, in line with the percentage of their crude imports that have interrupted. This represents a total of around 4% of diesel/gas oil demand and 2% of gasoline demand. However, there might be a more than proportional effect on exports to the UK, if exports are cut in favour of satisfying domestic demand. Potentially, all exports to the UK could be disrupted, representing a total of around 17% of diesel/gas oil demand and 13% of gasoline demand.

Under an assumption of low refining capacity or high case demand, additional product imports are likely to come from the Middle East and Asia-Pacific rather than from Europe, so the impact on product markets is likely to be similar.

Table 24: European product market interruption following a Baltic port disruption

Estimated export destinations from Baltic ports	Net interrupted volumes (kbd, 2008)	% of crude imports	Impacted UK diesel/gas oil imports		Impacted UK gasoline imports	
			kt/day	(% of demand)	kt/day	(% of demand)
Belgium	180	26%	0.4 - 1.6	1% - 2%	0.4 - 1.5	1% - 3%
Finland	130	57%	0 - 0.1	0% - 0%	n/a	n/a
France	150	9%	0 - 0.3	0% - 0%	0.1 - 1.6	0% - 4%
Netherlands	210	21%	1 - 4.9	1% - 6%	0.8 - 3.6	2% - 8%
Sweden	100	23%	1.3 - 5.5	2% - 7%	0.3 - 1.2	1% - 3%
Total	**770**		**2.8 - 13.2**	**4% - 17%**	**1.6 - 8**	**3% - 17%**

Source: IEA, Deloitte analysis

The impact of this interruption would be experienced by the UK with a time lag. On average, a cargo of Russian crude will arrive every six days, with a shipping time of 7 to 8 days (including loading and unloading time). This suggests that the UK would have a minimum of 7 days warning in which to order and receive an alternative cargo. These timescales would be extended for European product imports.

[64] Aviation fuel imports are negligible and have not been included.

Measures to mitigate the interruption

Alternative crude imports

Russia produces primarily medium sour crude from its West Siberian basin, although some Baltic Sea exports might also include the sweeter crude production from the Timan-Pechora basin.

An interruption to Russian exports will lead to a rapid market response, as the price of grades seen as immediate replacements are bid up. These are likely to include supplies from areas which are geographically closer to Europe, such as West and North Africa. As outlined in Section 5.2, there will be a three to six week lag while refiners respond to the price incentives and recalibrate their crude slates. Additional production is again likely to come from the spare capacity in Saudi Arabia. Although this does not offer an immediate substitute for the Russian Urals blend – Middle Eastern crudes typically have a sulphur content of greater than 2%, while the Urals blend has a sulphur content of around 1.3% - a refiner able to process Urals might instead be able to process some Saudi crude as long as this was blended with some sweeter crudes[65]. In the current environment, replacement production capacity would be readily available following a disruption of this magnitude, although there is likely to be a significant price disruption. In a tighter environment, this price disruption would be more extreme. Price impacts are discussed further at the end of this section.

By the same mechanism, European refiners would also seek to obtain alternative crude supplies to produce product for both their domestic markets and for export to the UK.

Increased domestic production to replace lost product imports

Depending on levels of UK refining utilisation, increased throughput would allow additional production to offset the lost product imports. This is of course reliant on sufficient additional crude volumes being sourced. These additional crude imports would almost certainly need to be of light, sweet crude to match spare refinery capacity.

The following table shows the volumes of product imports from Europe which might be disrupted during a three week interruption, as well as the additional product volumes that could be produced by increasing UK refining utilisation to a theoretical 90%. In both the base and low refining capacity scenarios, this could not generate enough additional volumes if all imports from countries affected by the Russian disruption were interrupted. Sufficient additional volumes could be produced to cover a smaller disruption in imports, although it is more likely that there will be a shortfall for diesel/gas oil. Nevertheless, the ability of domestic refineries to increase throughput offers at least some partial mitigation to this interruption.

It is important to note that there are two caveats to this conclusion, relating to diesel/gas oil production. First, we have assumed that increased utilisation results in product yields which are similar to current averages. However, refineries may already be maximising diesel/gas oil yields and increased throughput may result in more limited additional diesel/gas oil production (for example, if conversion capacity is fully utilised and there is only spare distillation capacity). Second, diesel/gas oil imports are in fact primarily diesel imports, and increased utilisation may not result in

[65] The sulphur content of crude can be adjusted through blending crudes of different sulphur content.

the required volume of additional diesel production. We have therefore assumed that only 50% of theoretical spare capacity is actually available for diesel/gas oil.

Table 25: Additional production through increase in UK refinery utilisation

Product	Interrupted import volumes (kt/day)	Additional production through increased utilisation to 90% (kt/day)	
		Base refining capacity	Low refining capacity
Diesel/gas oil	2.9 - 13.2	3.3	2.4
Gasoline	1.1 - 5.9	5	3.7

Source: IEA; DECC Digest of UK Energy Statistics; Deloitte analysis

Diverted product exports

The UK currently produces a net excess of gasoline, which is set to increase by 2030. By diverting gasoline production which would otherwise have been exported, UK refiners could comfortably replace the volumes of gasoline interrupted both through the direct loss of Russian crude and the second-round loss of European product imports. This is both in the base refining capacity scenario and under the assumption of the closure of two refineries.

Again, the ability to reduce diesel/gas oil exports is far more constrained. This is because relatively low volumes of diesel/gas oil are exported and a proportion of these are likely to be of incorrect quality, as discussed in Section 5.4.

Stocks and inventory

Even if it were not possible to source alternative supplies of crude or product imports, stock levels are easily sufficient to last for the duration of this interruption for all products.

Table 26: Ability of CSO stocks to mitigate disruption to Russian crude exports

Product	Total volume of 3 week disruption (kt, 2008)		Shortfall in CSO product stocks (kt, 2008)	
	Base	Low refining	Base	Low refining
Gasoline	90	78	2,856	2,868
Diesel/Gas oil	150	133	6,681	6,698
Aviation fuel	22	18	1,703	1,707
Burning oil	10	8	505	507

Source: DECC, Digest of UK Energy Statistics
Note: Shortfall in CSO product stocks is calculated as the current stock levels less cumulative interrupted volume. A negative value means that stocks are unable to cover the full volume of the interruption.

Summary of net impact of interruption

Again, an interruption to Russian crude exports will cause a significant market disruption, with a 1mbd disruption currently likely to lead to an approximately 45% spot price increase to $104/bbl from current benchmark Brent price levels of £72/bbl. This will lead to a corresponding rationing of demand by consumers. The full extent of the price rise will persist for one to two months until refiners are able to adjust their slates and substitute away towards cheaper alternatives, although this will be outside the timescales of this particular interruption scenario. In the medium to long-term, the price decline following market rebalancing will depend on the extent to which increased Saudi production can make up the loss. We have noted that Saudi crude is more substitutable for the Russian Urals crude, with some blending, and so the eventual partial price reversion after rebalancing is likely to be greater than in the scenario examining an interruption to North Sea crude.

A disruption to Russian crude exports is likely to have only a small direct effect on the UK, given the low volumes imported. However, the second-round effects on the European product market through increased prices are likely to be significant, given the importance of Russia as a supplier to European refiners. This will filter through to the UK through product price increase.

In the event of any rigidities affecting the expected market response, any interruption would be somewhat mitigated by increased domestic production. Base domestic refining capacity may be able to reduce the diesel/gas oil disruption by an additional 0.9kt/day in comparison to the low refining case, but there could still be up to a 9.9kt/day shortfall in the worst case interruption scenario (where all relevant European imports are disrupted) because of structural limitations of UK refining. Diversion of product exports would be able to fully mitigate the interruption to gasoline and aviation fuel under assumptions of both base and low refining capacity, but would provide little or no ability to offset the diesel/gas oil disruption. Finally, existing stocks would be able to fully cover the disruption even in the absence of any other mitigating measure. This indicates that this scenario will lead to no physical interruption to the UK.

We summarise the effect of the various mitigation options in Table 27 below.

Table 27: Summary of mitigation measures for interruption to Russian crude

	Scale	Duration of disruption	Impact on UK	
			Base refining	Low refining
2008	1mbd	21 days *(Time to impact: 7 days)*	• 90 kbd crude imports *6% of crude demand* • 2 – 8kt/day gasoline imports *2% - 13% of 2008 demand* • 3 – 13 kt/day diesel/gas oil imports *4% - 17% of 2008 demand*	• 65 kbd crude imports *6% of crude demand* • 2 – 8kt/day gasoline imports *2% 13% of 2008 demand* • 3 – 13 kt/day diesel/gas oil imports *4% - 17% of 2008 demand*
2015	1mbd			
2030	1.3mbd			

Measures to mitigate interruption

Mitigation	Issues	Time	UK interruption	
			Base refining	Low refining
Sour heavy crude imports	• Spare capacity in Saudi Arabia offers a better replacement for Russian Urals blend with some blending, but will still need some time for market rebalancing	• Approx 2 weeks to increase production + 21 days transit (from Saudi via Suez)	Unable to mitigate interruption within timescales	
Imports of direct replacement grades, including sweet light crude imports	• Available initially only at a high price premium • Subject to other refiners switching to sourer slates and freeing up replacement grades, and additional sour crudes being made available in the medium term • Subject to tightness in market for replacement grades	• 5 – 16 days to access alternative imports • 1 – 2 months for market rebalancing	100% interruption for 5 – 16 days (at pre-shock demand level)	
Increased domestic production	• Likely to be already maximising middle distillate production • Assume 50% of theoretical spare capacity for diesel/gas oil • Subject to availability of additional sweet light crude	• 1 – 13 days	• Reduces gasoline interruption to 0 – 3.0 kt/day after 1 – 13 days • Reduces diesel/gas oil interruption to 0-9.9 kt/day after 1-13 days	• Reduces gasoline interruption to 0 – 4.3 kt/day after 1 – 13 days • Reduces diesel/gas oil interruption to 0.4 -10.8 kt/day after 1-13 days
Diversion of crude exports	• 800kbd exported from UKCS currently. Assumed to be 600kbd or more in 2015 and 300 kbd in 2030 • Primarily spot basis so no contractual obligation but price premium	• Immediate	No crude import interruption	
Diversion of product exports	• Substantial exports of gasoline • 1mt p.a of aviation fuel exports to Ireland (3kt/day); further 2.2kt/day unspecified exports • Very limited ability to divert diesel/gas oil exports due to quality issues	• Immediate	• No gasoline interruption • No aviation fuel interruption • Up to 13kt/day diesel/gas oil interruption (17% of 2008 demand)	• No gasoline interruption • No aviation fuel interruption • Up to 13kt/day diesel/gas oil interruption (17% of 2008 demand)

Product imports	• Subject to spare refining capacity	• 5 to 40 days, depending on source	100% interruption (at pre-shock demand levels) for 5 – 40 days
Stocks	• Able to use both crude and product stocks	• Immediate	No interruption
Immediate price impact following interruption			
45% price increase to $104/bbl from benchmark Brent spot price of $72/bbl			

Source: Deloitte analysis

6.3 Asian-Pacific refined product imports

Initial disruption

An interruption to a major export refinery in India will lead to the loss of around two to three million tonnes of aviation fuel (in annual terms), as well to the loss of other refined products. The majority of Indian refined product exports are targeted at other Asian markets, but Europe and particularly the UK forms a significant market for aviation fuel exports.

Although the UK currently imports only 0.9mt per year from India, this is likely to increase along with the UK's increasing import requirements and the new investments in India. The UK will require at least another 2mt of aviation fuel imports by 2015 and 5.5mt by 2030, under the assumption of base demand and current refining capacity. These requirements increase to 4mt and 9mt in 2015 and 2030, respectively, assuming high demand and reduced refining capacity. It is likely that some of these additional requirements will be sourced from India, and possibly from a single export-orientated refinery. We therefore assume that an interruption to an Indian refinery leads to the disruption of around 1.5mt of aviation fuel exports to the UK – scaled to a six month interruption period – as shown in the table below. The scale of this interruption would not increase under a scenario of high-case UK demand, as the volumes which can be sourced from a single Indian refinery are constrained.

Table 28: Volumes interrupted by 6 month Indian refinery outage

	2008	2015	2030
6 month aviation fuel interruption	1,250kt	1,250kt	1,250kt
Interruption to UK imports	380kt	750kt	750kt
% of domestic demand	6%	11%	8%

Source: IEA; Deloitte analysis

Aviation fuel is shipped to the UK in 70kt product tankers, with an average journey time of around 33 days with loading and unloading. Under the assumption that an annual 1.5mt of aviation fuel is being sourced from the interrupted refinery, this implies that a shipment is scheduled to arrive every 2.5 weeks.

Measures to mitigate interruption

Additional production from UK refineries

The deficiency in middle distillates suggests that most UK refineries are running to maximise production of aviation fuel/kerosene and diesel/gas oil at the expense of gasoline. However, as discussed in Section 5.3, relative yields of aviation fuel/kerosene and diesel/gas oil could be adjusted to increase aviation fuel/kerosene production. Moreover, with average utilisation of around 80%, there may be some potential to increase throughput to increase aviation fuel/kerosene production. However, this will be at the expense of yields, as it is likely that refineries are already maximising use of conversion capacity. Any spare capacity is more likely to be simple distillation capacity, which will result in much lower yields of middle distillates and higher yields of gasoline and low-value fuel oils.

Given a sufficient price rise for aviation fuel, refiners may be incentivised to substitute diesel/gas oil production for aviation fuel/kerosene production, or to increase throughput if the increased price for aviation fuel/kerosene is sufficient to offset possible losses from producing surplus gasoline and low-value products. Refineries therefore provide some limited potential to offset the loss in Indian imports. However, this is unlikely to be sufficient and so it will be necessary to source alternative imports.

Similarly, there is potential to reduce production of burning oil in order to increase aviation fuel production, as these two kerosenes differ only through very minor process changes. UK refiners currently meet almost all domestic demand for burning oil. Given sufficient prices for aviation fuel, refiners could be incentivised to divert production away from burning oil to aviation fuel. However, as discussed in Section 5.3, burning oil demand and production are generally concentrated in the winter months, offering limited ability to divert production in the summer months and meaning a considerable price premium would be required to incentivise reduced burning oil production in winter.

In general then, refineries offer only limited ability to increase aviation fuel/kerosene production, meaning that the UK will have to rely to a greater extent on alternative product imports in the case of an interruption.

Diversion of exports

There is only limited scope to divert aviation fuel exports to offset the loss of Indian imports. The only significant export destination is Ireland, which currently imports a million tonnes of aviation fuel from the UK annually, and diverting these exports is unlikely to be politically feasible.

Alternative product imports

The market for aviation fuel is relatively deep as there is a single uniform specification accepted internationally. There are a variety of alternative sources of aviation fuel which would currently be easily sufficient to cover an interruption of this magnitude, including the following.

- **Europe:** the Indian government caps domestic prices of oil products, meaning that low domestic fuel rates have led private refiners – such as Reliance – to have an overt export focus in order to avoid suffering financial losses in the domestic market. The considerable new refining capacity brought on by Reliance has therefore been focused on export markets, including European markets, where its size and efficiency have meant it is able to undercut older and less efficient refineries in Europe. According to market traders, this has led to a fall in utilisation in Europe, which could be reversed in response to the disruption[66].

- **Middle East:** Middle Eastern refiners would be likely to increase production, given sufficient price incentives. Kuwaiti and Saudi refineries can recalibrate refining production to maximise aviation fuel production, in the so-called ‘max jet’ mode. This would increase yields from around 18% to 24%-25% of production.

- **United States**: the large US refining base is able to produce significantly more aviation fuel if required, particularly if price incentives cause the Venezuelan aviation fuel production, which usually supplies the US, to be diverted to Europe.

The continued ability of alternative sources to increase utilisation to offset a disruption will depend on the tightness of the refining market. In Europe, in particular, low utilisation rates are predicted at least until 2015, although there is less certainty beyond 2015 (see Section 5.2 for a further discussion). However, the ability to adjust middle distillate yields by producing less diesel/gas oil and more aviation fuel will provide some flexibility by spreading any tightness across the middle distillates market as a whole.

The timeframes for accessing alternative product supplies will depend on the source. Transportation time from European refineries is generally less than one week; this increases to 15 to 17 days for deliveries from US or Venezuelan refiners. The long transportation time for delivery from Indian refineries – 33 days – provides time to respond and source alternative product.

Stocks and inventories

Current stock levels would be sufficient to last for the duration of this interruption without any other form of mitigation, even for the increased level of disruption in 2015 and 2030. This is shown in Table 26 below. However, it is important to note that stocks held in the form of product rather than crude will be needed to mitigate a disruption in product imports. If the balance between stocks held in the form of crude and those held in the form of product were to change so that less product stock was held, there could potentially be a shortfall in stocks.

[66] However, we note that it is not clear how much of the spare capacity can be used for middle distillate production.

Table 29: Ability of CSO stocks to mitigate disruption to Indian aviation fuel imports

Aviation fuel	Total volume of 6 month disruption (kt)	2008 CSO stocks held as product (kt)	Shortfall (kt)
2008	380		734
2015	750	1,116	366
2030	750		366

Source: DECC, Digest of UK Energy Statistics
Note: Shortfall in CSO product stocks is calculated as the current stock levels less cumulative interrupted volume. A negative value means that stocks are unable to cover the full volume of the interruption.

Summary of net impact of disruption

Additional product imports will require a price increase to incentivise other refiners to increase production or divert existing production towards aviation fuel. However, the price increase resulting from an aviation fuel market disruption varies depending on estimates of the size of the affected market. World demand for aviation fuel was an annual 239mt in 2008[67], implying that a (annual equivalent) disruption of 2.5mt would represent around a one percent fall in supply and would lead to a price increase of 17%. This would increase the Amsterdam-Rotterdam-Antwerp (**"ARA"**) spot price for aviation fuel from its January 2010 average of $678.42/tonne to $796.78/tonne.

However, it is likely that some parts of the market would be initially relatively insulated from a disruption. For example, those refineries that produce solely for domestic markets would only experience changing price incentives once the relative scarcity of aviation fuel trickled through to their internal markets. Other markets might also be initially insulated through geographic distance; for example, the US market for aviation fuel is likely to be initially less affected than Europe by an Asian-Pacific interruption by its geographic distance as well as its depth. Full price effects would take around six weeks to diffuse through the entire market. This suggests that the initial price spike would reflect the impact of a proportionally larger disruption in a smaller market. If we assume the immediately affected market consists of roughly half the total market[68], then the loss of 2.5mt of annual equivalent production would represent around a two percent fall in supply and would lead to a price increase of 35% to $915.13/tonne.

In future, the size and duration of a price increase will depend on the levels of spare capacity in the refining market. In 2015, low levels of European refinery utilisation suggest that the price increase will be moderate; if middle distillate markets become tighter beyond 2030 then higher prices will be needed to incentivise sufficient additional production. In general, however, the resilience of the UK to interruptions is significantly increased by the presence of a large European refining base in close proximity.

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[67] Energy Intelligence Group, Jet Fuel Intelligence, 1 February 2010. Available at http://www.energyintel.com/DocumentDetail.asp?document_id=656443. Estimates based on IEA OECD and non-OECD balances.

[68] This approximates to the combined size of the European, Asian-Pacific (excluding China) and Middle Eastern markets, which are likely to be the most affected by an Indian refinery interruption.

In the event that market rigidities prevent alternative product imports being sourced, domestic refining capability offers only limited potential to offset the interrupted volumes. The increased refining capacity of the base scenario is only sufficient to offset an additional 0.2kt/day in comparison to the low refining scenario. Similarly, the ability to divert product exports can only offset the interruption by an additional 0.6kt per day in the base refining case. That said, aviation fuel stocks are sufficient to cover the disrupted volumes in this scenario and avoid any physical interruption, assuming the market is unable to provide replacement volumes.

Table 30 summarises the impact of the various mitigation measures available to offset an interruption to Indian aviation fuel imports.

Table 30: Measures to mitigate Indian aviation fuel interruption

	Scale	Duration of disruption	Impact on UK	
			Base refining	Low refining
2008	6.8kt/day	180 days *(Time to impact: 33 days)*	2.5kt/day aviation fuel *(6% of demand)*	
2015			4.1 kt/day aviation fuel *(11% of demand)*	
2030			4.1 kt/day aviation fuel *(8% of demand)*	

Measures to mitigate interruption

Mitigation	Issues	Time	UK interruption	
			Base refining	Low refining
Sour heavy crude imports	Not applicable as an independent mitigating measure			
Imports of direct replacement grades	Not applicable as an independent mitigating measure			
Increased domestic production	• Likely to be already maximising production of middle distillates • Some limited ability to adjust relative yields of diesel/gas oil and aviation fuel, or to replace burning oil production • Assume 50% of theoretical spare capacity • Subject to availability of additional sweet light crude	• 1 – 2 days	• 2008: Reduces aviation fuel interruption to 1.7 kt/day after 1 – 2 days • 2015/2030: Reduces aviation fuel interruption to 3.3 kt/day after 1 – 2 days	• 2008: Reduces aviation fuel interruption to 1.9 kt/day after 1 – 2 days • 2015/2030: Reduces aviation fuel interruption to 3.5 kt/day after 1 – 2 days
Diversion of crude exports	Not applicable as an independent mitigating measure			
Diversion of product exports	• 1mt p.a of aviation fuel exports to Ireland (3kt/day) • Further 2.2kt/day unspecified exports • We assume these decrease proportionally with low refining capacity	• Immediate	• No interruption if divert all exports • 1.8kt/day interruption if divert all except Irish exports	• No interruption if divert all exports • 2.4kt/day interruption if divert all except Irish exports
Product imports	• Subject to spare refining capacity • Relatively deep market for aviation fuel	• 6 to 41 days, depending on source	100% interruption for 6 – 41 days (at pre-shock demand levels)	
Stocks	• Restricted primarily to stocks in product form	• Immediate	No interruption	No interruption

Immediate price impact following interruption

Immediate impact: up to 35% price increase to $915/tonne from ARA spot of $678/tonne

Longer-term impact (without any mitigations or market adjustment): up to 17% price increase to $797/tonne from ARA spot of $678/tonne

Source: Deloitte analysis

6.4 Interruption to Saudi crude

Initial disruption

The direct impact of a net disruption of 1mbd of crude oil exports from Saudi Arabia on the UK is limited, as the UK currently does not import crude oil from Saudi Arabia. Similarly, only around 7% of OECD-Europe crude imports are from Saudi Arabia.

However, second-round effects will impact the UK. Saudi Arabia exports considerable volumes of crude to Asian-Pacific refiners, which currently supply some 20% of UK aviation fuel requirements. Imports from this region are likely to increase over time as demand for aviation fuel increases, particularly under the assumption of reduced domestic refining capacity. Furthermore, the US currently imports some 1.5mbd from Saudi Arabia, representing 15% of crude imports. An interruption to these imports may lead to tightening in alternative crude markets which also supply the UK, such as West and North Africa.

We have examined the possible impact on UK imports of aviation fuel from Asian-Pacific refiners. This depends on assumptions around the increase in UK imports, and the share of these met by Asian-Pacific refiners, and the reduction in Asian-Pacific exports following a fall in Saudi crude production.

We have assumed that 50% of the increase in UK aviation fuel imports is met by Asian-Pacific refiners. Furthermore, we have tested two alternative assumptions regarding the reduction in Asian-Pacific imports. The low interruption assumption is that these exports fall in proportion to the fall in Saudi Arabian crude exports (i.e. by 12%). However, Asian-Pacific refiners may choose to decrease exports by a more than proportional amount to favour other markets or domestic consumers. The high case assumption is that all UK imports are disrupted, subject to an upper bound. This is the aviation fuel yield from 1mbd of crude.

We note that the high case interruption scenario also reflects the additional imports which might be required under a high-case UK demand scenario.

Table 31: Aviation fuel volumes interrupted from Asian-Pacific refiners

	Base refining capacity			Low refining capacity		
	2008	2015	2030	2008	2015	2030
Assumed aviation fuel imports from Asian refiners	7.4	9.9	15.1	7.4	12.2	17.3
Low case interruption	0.9	1.2	1.2	0.9	1.5	1.5
% of demand	3%	3%	2%	3%	4%	3%
High case interruption	7.4	9.9	9.9	7.4	12.2	12.2
% of demand	21%	26%	20%	21%	32%	25%

Source: Deloitte analysis, DECC Digest of UK Energy Statistics

Measures to mitigate interruption

Alternative crude imports

Although the UK does not source any crude from Saudi Arabia – and only negligible amounts from the Middle East in general – an interruption to Saudi crude exports is likely to lead to increased competition for other sources of crude. There are no technical constraints on replacing a sourer feedstock with a sweeter grade, and so there may be increased pressure on UK source markets such as West and North Africa. This will have a greater impact under the assumption of base refining capacity than under reduced domestic refining capacity assumptions.

However, we note that the sweetness of the UK slate will insulate it to some extent from a crude market disruption, as the price premium on higher quality grades will encourage refiners to look first for alternatives which are closer in grade to the sour Saudi crude. Moreover, the UK's geographical proximity to North Sea production means that it will have a price advantage in terms of freight savings over competitors. Nevertheless, a price spike for all grades of crude is likely following the interruption.

In general, the impact of an interruption on crude markets will depend on spare capacity in the market. Saudi Aramco has significantly greater flexibility than other producers in not only its spare production capacity but also in its production infrastructure. As we have noted in Section 4.2.4, Saudi Arabia has a range of alternative export outlets and between 3 and 4mbd of spare exporting capacity. It also has over 3mbd of shut-in capacity currently. It is likely that it would be able to adjust production and export routes in a few weeks to divert flows and offset the interruption. Future spare capacity is less certain. However, Saudi has historically developed more productive capacity than it can utilise in order to be able to play a stabilising role on the world market, and it is likely that this will continue given concerns around the demand destruction that would be triggered by sustained high prices.

Increased domestic production and diversion of exports

As we have noted in our discussion of an Indian refinery disruption (see Section 6.3) UK refineries offer some limited potential to increase aviation fuel production by increasing utilisation (provided additional crude supplies are available) or by substituting away from diesel/gas oil or burning oil production. This could partially mitigate against a disruption in aviation fuel imports from Asian-Pacific refiners affected by a Saudi crude interruption. However, the lack of additional conversion capacity and demand for other middle distillates suggests that this mitigation will be limited, and it is very likely that alternative product imports will still need to be found.

Similarly, there is little opportunity to divert exports of aviation fuel as the only significant export destination is Ireland.

Alternative product imports

Our discussion of an Indian refinery disruption (see Section 6.3) has indicated that there is likely to be sufficient alternative capacity available to offset an interruption in imports of this scale, subject to availability of crude feedstock. Europe in particular is relatively insulated from an interruption in

Saudi crude as it relies more heavily on crude imports from Russian, North Sea, African and Caspian producers.

Net impact of interruption

Given the sensitivity of markets to crude interruptions, particularly from the Middle East, an interruption to crude supplies from Saudi Arabia of 1mbd would inevitably lead to a large spike in prices which would filter through to the rest of the crude market given the substitutability of sweeter grades for Saudi production. This interruption represents a 1.2% fall in supply, which would result in around a 45% increase in the price of crude, to $104/bbl. This price shock may subside over time given the presence of spare productive capacity and flexibility in export routes in Saudi Arabia, depending on the nature of the interruption and whether Saudi is able to offset the loss in production.

The magnitude of the associated disruption to aviation kerosene imports from Asian Pacific refiners is unclear, and depends on whether these refiners choose to reduce exports by proportionally more than the fall in crude imports. Increased domestic production offers some limited ability to mitigate the interruption, with the maximum interruption reduced by 0.8kt/day with base refining capacity in comparison to 0.6kt/day with low refining capacity. Similarly, diverting all product exports can reduce the maximum disruption to 4.6kt/day with base refining capacity compared to 8.3kt/day with low refining capacity. This however requires the diversion of exports to Ireland, which may not be politically feasible.

Although domestic refining capacity allows some limited potential to offset any shortfalls, the structural shortage of middle distillate production capacity means that it is likely that alternative imports will need to be sourced both with base and reduced refining capacity. This is exacerbated by the inadequacy of existing product stocks to offset the maximum interruption. If stocks were relied upon as the only mitigation measure, there would be a shortfall equivalent to a maximum of 14 days of demand in the base refining case and 24 days of demand in the low refining case.

Table 30 summarises the impact of the various mitigation measures available to offset an interruption to Saudi crude exports.

Table 32: Impact of measures to mitigate Saudi crude interruption

	Scale	Duration of disruption	Impact on UK	
			Base refining	Low refining
2008	1mbd	180 days *(Response time: 38 – 58 days)*	0.9- 7.4kt/day aviation fuel *(3-21% of demand)*	0.9- 7.4kt/day aviation fuel *(3-21% of demand)*
2015			1.2- 9.9kt/day aviation fuel *(3-26% of demand)*	1.5- 12.2kt/day aviation fuel *(4-32% of demand)*
2030			1.2- 9.9kt /day aviation fuel *(2-20% of demand)*	1.5- 12.2kt /day aviation fuel *(3-25% of demand)*

Measures to mitigate interruption

Mitigation	Issues	Time	UK interruption	
			Base refining	Low refining
Sour heavy crude imports	Not applicable as an independent mitigating measure			
Imports of direct replacement grades	Not applicable as an independent mitigating measure			
Increased domestic production	• Likely to be already maximising production of middle distillates • Some limited ability to adjust relative yields of diesel/gas oil and aviation fuel, or to replace burning oil production • Assume 50% of theoretical spare capacity • Subject to availability of additional sweet light crude	• 1 – 2 days	• 2008: Reduces aviation fuel interruption to 0 – 6.5 kt/day after 1 – 2 days • 2015/2030: Reduces aviation fuel interruption to 0.4 –9.1 kt/day after 1 – 2 days	• 2008: Reduces aviation fuel interruption to 0.3 – 6.8 kt/day after 1 – 2 days • 2015/2030: Reduces aviation fuel interruption to 0.9 – 11.6 kt/day after 1 – 2 days
Diversion of crude exports	Not applicable as an independent mitigating measure			
Diversion of product exports	• 1mt p.a of aviation fuel exports to Ireland (3kt/day) • Further 2.2kt/day unspecified exports • We assume these decrease proportionally with low refining capacity	• Immediate	• No interruption in low interruption case even without diverting Irish exports • High case: 2.1kt/day (2008) and 4.6kt/day (2015/2030) interruption if divert all exports; 5.1kt/day (2008) and 9.9kt/day (2015/2030) interruption if divert all exports except Irish exports	• No interruption in low interruption case even without diverting Irish exports • High case: 3.5kt/day (2008) and 8.3kt/day (2015/2030) interruption if divert all exports; 5.7kt/day (2008) and 10.5kt/day (2015/2030) interruption if divert all exports except Irish exports
Product imports	• Subject to spare refining capacity • Relatively deep market for aviation fuel	• 6 to 41 days, depending on source	100% interruption for 6 – 41 days (assuming pre-shock demand)	
Stocks	• Restricted primarily to stocks in product form • Based on 2008 stocks	• Immediate	• No interruption in low interruption case	• No interruption in low interruption case

			• Inadequate stocks in high interruption case: interruption of full daily demand for 2 days (2008), 14 days (2015), 11 days (2030)	• Inadequate stocks in high interruption case: interruption of full daily demand for 2 days (2008), 24 days (2015), 19 days (2030)
Immediate price impact following interruption				
45% price increase to $104/bbl from benchmark Brent price of $72/bbl				

Source: Deloitte analysis

6.5 Refined product exports from the Netherlands

Initial disruption

Rotterdam's role as a European trading hub means that a three week interruption to the port will cause a major logistical disruption. Crude imports to the four key Rotterdam refineries will be interrupted, as will crude imports to inland German and Belgian refineries, forcing them to rely on stocks or shut down production. Both exports and imports of refined products will also be interrupted.

Without a more detailed technical study, it is not possible to determine the exact consequences of an incident of this nature. This will depend on the extent to which imports and exports are diverted via other routes including rail, barge and road, and on the use of stocks and inventories. For the purpose of this analysis, therefore, we have made the following assumptions.

- Sea-borne exports from Rotterdam, including those to the UK, are completely interrupted.
- Inland refineries which are fed by pipeline from Rotterdam are unable to access alternative crude imports due to their relatively isolated positions, but rely on stocks held at refineries and product stocks to satisfy domestic demand. The same assumption is made for inland demand centres receiving product imports via pipeline from Rotterdam.

Our discussion focuses on the disruption to diesel/gas oil exports. This is because the Netherlands exports only negligible volumes of aviation fuel[69] from its sea ports. Furthermore, not only are a large proportion of gasoline exports routed via Amsterdam, but even in our low refining capacity scenario the UK produces a surplus of gasoline and so is unlikely to be adversely impacted by a disruption to Dutch gasoline imports.

The table below shows the main sea-borne export destinations of diesel/gas oil from the Netherlands, and assumptions about the proportion of these from Rotterdam.

[69] However, considerable volumes are transited inland via pipeline and barge to Germany and Belgium.

Table 33: Estimated sea-borne exports of gas oil/diesel from the Netherlands

Exports to	Volume (kt p.a.)	Assumed % via Rotterdam
United Kingdom	1,929	100%
Belgium*	7,207	80%
France	803	80%
Spain	954	80%
Africa	1,726	80%
Total disruption over three week period	600kt	

Source: IEA. Port of Rotterdam and Amsterdam statistics

** Although Rotterdam and Belgium are connected via pipeline, this is solely for the transport of crude.*

As is shown in Table 33, exports of approximately 1.9mt p.a of diesel/gas oil are reported from the Netherlands. This represents around 7% of current demand and 25% of current imports. UK demand for diesel/gas oil is projected to increase between now and 2030, particularly under assumptions of reduced refining capacity or high-case demand assumptions. However, recent trends indicate that most of the additional import volumes will be sourced not from Europe but rather from the Middle East, US and Asia-Pacific. This suggests that an incident affecting Rotterdam would impact a similar level of imports in the future.

The timeframes for responding to an interruption in Dutch diesel/gas oil imports are relatively short. Transporting product from Rotterdam to the UK takes roughly half a day in terms of sailing time and a further two days to load and unload on each end. At a minimum, the UK would have 2.5 days warning of the effect of an interruption in Dutch exports if the interruption occurred when a shipment was already loaded and waiting to depart from the port of Rotterdam.

Shipments from the Netherlands are transported in smaller cargo sizes given the short distances, usually in 30 kt DWT vessels. Assuming the use of 30 kt DWT vessels, UK imports from Rotterdam average about 65 shipments over the course of a year, or roughly just over one shipment a week. A three week interruption to Rotterdam's export activities would result in the loss of an average 5.3 kt per day of UK diesel/gas oil imports, or almost four shipments' worth over a three week period.

Mitigating measures

Increased domestic production

The deficiency in middle distillates suggests that most UK refineries are running to maximise production of aviation fuel/kerosene and diesel/gas oil at the expense of gasoline. However, as discussed in Section 5.3, relative yields of aviation fuel/kerosene and diesel/gas oil could be adjusted to increase diesel/gas oil production. There might also be some potential to increase throughput to increase all production, given average utilisation of around 80%. However, this will be at the expense of yields, as it is likely that refineries are already maximising use of conversion capacity. Any spare capacity is more likely to be simple distillation capacity, which will result in much lower yields of middle distillates and higher yields of gasoline and low-value fuel oils. Given sufficient price incentives, refiners might increase relative yields of diesel/gas oil, or increase throughput if the increased price for diesel/gas oil is sufficient to offset possible losses from producing surplus gasoline and low-value products. Refineries therefore provide some potential to offset the loss in diesel/gas oil imports.

However, the aggregation of diesel and gas oil trade data means it is difficult to quantify the extent to which increased domestic production can offset the loss of diesel/gas oil imports. Some 80% of UK gas oil/diesel consumer demand is for diesel rather than gas oil. This, and the relatively low desulphurisation capacity of the UK refining industry, suggests that proportionally more of diesel/gas oil imports might be diesel. UK refiners' ability to increase diesel production is more limited than the ability to product more gas oil, given the additional desulphurisation processing required. There may be some flexibility for UK refiners to process some additional gas oil into diesel, but this is probably limited. Even with base refining capacity, the UK may have to rely to a greater extent on alternative product imports in the case of an interruption.

Export diversion

The UK exports around 6mt of diesel/gas oil annually. It may be possible to retain these exports and offset the loss of Dutch imports. However, we have discussed in Section 5.4 how issues of specification, blendstocks and the proportional split between diesel and gas oil means that the extent to which exports can be diverted is not clear. This suggests that while greater refining capacity may provide some further resilience by allowing some diversion of exports, this is likely to be limited.

Alternative product imports

The primary mitigation of an interruption to gas oil/diesel imports is to source additional product imports. The UK is far less exposed than inland European demand centres supplied by Rotterdam to a disruption to Rotterdam trade due to its island nature.

There are a number of alternatives for replacing the lost exports.

- Product ships intended for Rotterdam could be diverted away to alternative destinations. In 2008, inbound flows of 32mt and outbound flows of 22mt of refined oil products were reported by the port authorities. While no data is available on the product mix, inbound flows could be temporarily be diverted to other destinations to offset the interruption in exports. The UK would benefit through its island nature and proximity to Rotterdam. It also has facilities for ship-to-ship transfers if the product ships are too large for some UK terminals.

- Spare capacity in European refining suggests that some of the additional requirements could be absorbed within Europe. Although inland demand centres supplied by Rotterdam would also be seeking alternative products, their more isolated locations mean that they may not have access to the production of other European refineries. Given the likely price incentives, European refineries with export routes may be incentivised to increase production in response. Current low utilisation levels – which are forecast to increase in 2015 – suggest that some additional production is possible. We note that the combination of low European utilisation levels and gas oil/diesel imports from the US, Middle East and Asian-Pacific (some

17mt to OECD-Europe in 2008) is for economic reasons, as in this case it is cheaper to import than to produce domestically.

- Given longer timescales, additional product imports would be available with longer delivery times from the US and Middle East. In particular, diesel/gas oil exports from the US are likely to grow, and alternative imports could reach the UK distribution network within 14 days.

Utilisation of inventory and stock

Some 4mt of gas oil/diesel stocks are currently held in product form in the UK. This is easily sufficient to replace a three week interruption in diesel/gas oil imports. Total consumer demand for diesel gas oil over a three week period reaches a maximum of 2.2mt in 2030 under high demand case assumptions.

However, the location of the storage is a potential consideration. IEA requirements allow CSO stock to be held in other countries under ticketing arrangements. If these stocks were held in the Netherlands, they may be inaccessible during a disruption of this nature.

Net impact of interruption

An interruption to Rotterdam would cause significant logistical disruption due to its key position. The extent of the resulting price disruption would depend on the net impact of the disruption. For simplicity, we have assumed the port interruption leads to the loss of the sea-born exports from Rotterdam, and do not factor in any offsetting effect of diverting import shipments originally bound for Rotterdam.

As described in Section 6.3, the immediate price effect depends on the size of the market which is initially impacted. World demand for diesel/gas oil was approximately 1,145mt in 2008[70], implying that an (annual equivalent) disruption of 10.5mt would represent just under a one percent fall in supply and would lead to a price increase of 15%. This would increase the Rotterdam spot price for gas oil[71] from its January 2010 average of $624.61/tonne to $719.83/tonne.

As for aviation fuel, some parts of the market would be initially relatively insulated from a disruption, particularly those that are geographically distant from Europe. Again, full price effects would take around six weeks to diffuse through the entire market. This suggests that the initial price spike would reflect the impact of a proportionally larger disruption in a smaller market. If we assume the immediately affected market consists only of Europe, then the loss of 10.5mt of annual equivalent production would represent around a three percent fall in supply and would lead to a price increase of 49% to $928.83/tonne. It is more likely though that the impact will quickly spread to affect more than Europe so the initial price spike may not be as extreme.

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70 IEA, Medium-Term oil market report, June 2009 and IEA, Oil Market Report, December 2009. These figures do not include demand for Africa.

71 The price of diesel is generally set as a premium to gas oil.

The product price increase would incentivise the market to produce additional product. Subject to refining capacity and depending on the source of the alternative imports, these could offset the interruption in between 5 and 41 days.

In the absence of a market response, domestic refining capacity offers only a limited ability to offset the loss of imports from Rotterdam. The base refining capacity scenario enables the disruption in imports to be reduced to 2kt/day though additional domestic production, in comparison to 2.9kt/day in the low refining capacity scenario. There is also very limited capacity for product exports to be diverted, due to quality issues. However, product stocks are able to fully offset the interruption and avoid any physical interruption to the UK, subject to a majority of the stocks not being held in the Netherlands.

Table 34 summarises the impact of the various mitigation measures available to offset an interruption to the port of Rotterdam.

Table 34: impact of mitigations following interruption to Rotterdam

	Scale	Duration of disruption	Impact on UK	
			Base refining	Low refining
2008 2015 2030	29kt/day diesel/gas oil	21 days *(Response time: 2.5 days)*	5.3kt/day diesel gas oil *(7%-8% of demand)*	

Measures to mitigate interruption

Mitigation	Issues	Time	UK interruption	
			Base refining	Low refining
Sour heavy crude imports	Not applicable as an independent mitigating measure			
Imports of direct replacement grades	Not applicable as an independent mitigating measure			
Increased domestic production	• Likely to be already maximising production of middle distillates • Imports might be weighted towards diesel for which there is more limited spare capacity • Assume 50% of theoretical spare capacity • Subject to availability of additional sweet light crude	• 1 – 2 days	• 2008: Reduces diesel/gas oil interruption to 1.9 kt/day after 1 – 2 days • 2015/2030: Reduces diesel/gas oil interruption to 2 kt/day after 1 – 2 days	• 2008: Reduces diesel/gas oil interruption to 2.9 kt/day after 1 – 2 days • 2015/2030: Reduces diesel/gas oil interruption to 2.9 kt/day after 1 – 2 days
Diversion of crude exports	Not applicable as an independent mitigating measure			
Diversion of product exports	• Very limited ability to divert diesel/gas oil exports due to quality issues	• Immediate	No mitigating impact	
Product imports	• Ability to divert cargoes intended for Rotterdam • Subject to spare refining capacity	• 5 to 41 days, depending on source	100% interruption for 5 – 41 days (assuming pre-shock demand)	
Stocks	• Restricted primarily to stocks in product form • Some stocks may be located in the Netherlands	• Immediate	No interruption	No interruption

Immediate price impact following interruption

Immediate impact: up to 49% price increase if only European markets are affected. This is an increase to $929/tonne from ARA spot of $625/tonne

Longer-term impact (without any mitigations or market adjustment): up to 15% price increase to $720/tonne from ARA spot of $625/tonne

Source: Deloitte analysis

6.6 UK refinery interruption

Initial disruption

We have considered an interruption to Fawley refinery caused by mechanical or technical failure. Fawley has the highest nameplate capacity of the UK's current refinery stock, with an approximate capacity of 326kbd. Assuming a utilisation of 81.5% in line with our supply scenarios, a three week interruption would remove approximately 0.76mt of processed crude from the UK's system over the course of the 21 day disruption. Table 35 shows the volumes of refined product that this represents, given average UK refinery product yields.

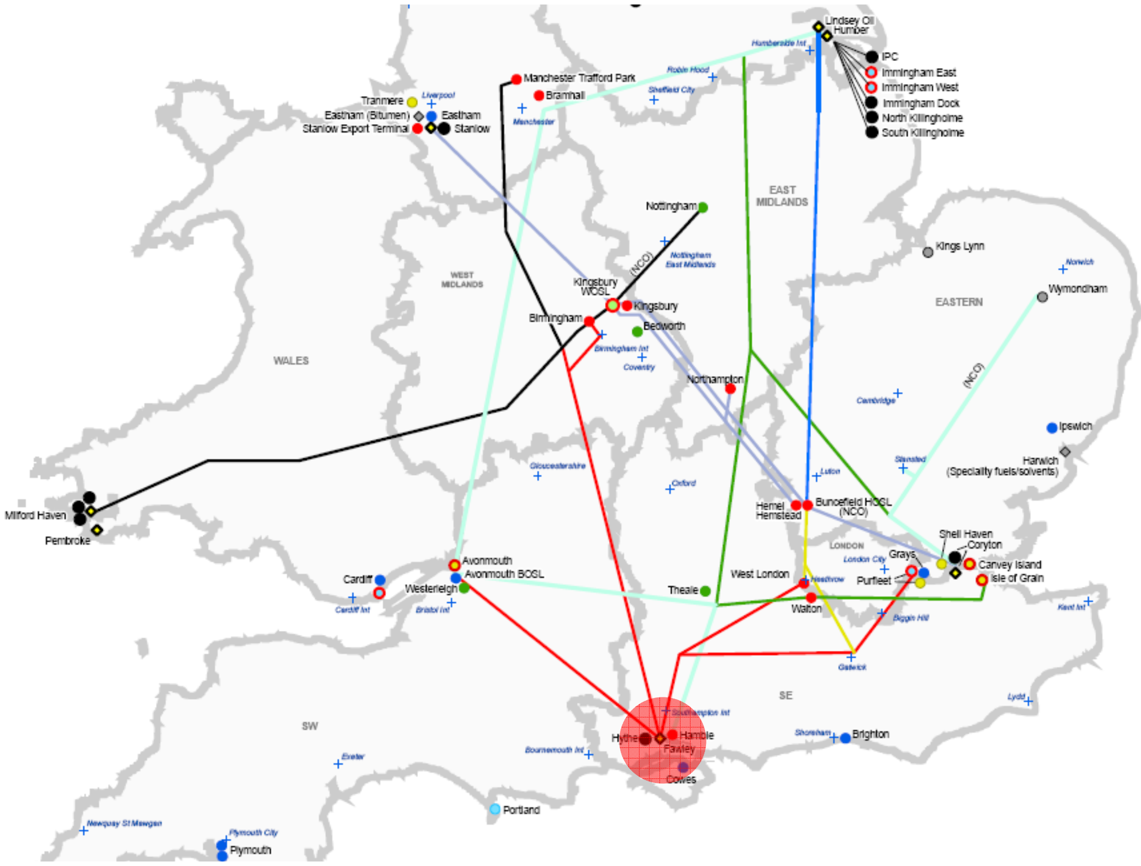
Table 35: Volumes interrupted by a three week Fawley refinery outage

	2008		2015		2030	
	Base	Low	Base	Low	Base	Low
Total disruption (kbd)	266		266		266	
% of domestic production	18%	26%	18%	26%	18%	26%
Interruption to refined products	**Kt/day**	**% of demand**	**Kt/day**	**% of demand**	**Kt/day**	**% of demand**
Gasoline	9.7	21%	9.7	29%	9.7	38%
Diesel/Gas oil	12.9	17%	12.9	16%	12.9	17%
Aviation fuel	3.1	9%	3.1	8%	3.1	6%
Burning oil	1.5	14%	1.5	18%	1.5	22%

Source: Digest of Energy Statistics UK, Deloitte analysis

The refined product from Fawley is distributed to London, the South East, South West, West Midlands and Manchester Fuel Terminal, as shown in Figure 36 below. It is a major aviation fuel supplier to airports, with a dedicated pipeline to Heathrow and a multiproduct pipeline routed via Gatwick. Approximately 85% of the refined product is distributed by pipeline, a further 10% by sea and the final 5% through both road and rail.

Figure 36: Fawley's downstream infrastructure location and pipelines



Source: DECC

Measures to mitigate the interruption

Increased domestic production

The loss of production from Fawley may be partially offset by increased production at other domestic refineries. However, Fawley's large productive capacity means that this is unlikely to be sufficient to replace fully the lost output. Table 36 below shows that an increase in the utilisation of the remaining refineries to 90% is insufficient to offset the lost production under both base and low refining capacity scenarios. The remaining disrupted volumes are greater under the assumption of low refining capacity.

Table 36: Remaining disrupted product volumes after increased refinery production, kt

	Original disruption	Remaining disrupted volumes, base scenario			Remaining disrupted volumes, low scenario		
		2008	2015	2030	2008	2015	2030
Diesel/gas oil	12.9	10.1	10.2	10.2	10.4	11.1	11.1
Aviation fuel	3.1	2.5	2.5	2.5	2.5	2.7	2.7
Burning Oil	1.5	1.2	1.2	1.2	1.2	1.3	1.3
Gasoline	9.7	5.5	5.6	5.6	5.9	7.0	7.0
		Proportion of disruption mitigated by spare capacity utilisation, base scenario			Proportion of disruption mitigated by spare capacity utilisation, low scenario		
		2008	2015	2030	2008	2015	2030
Diesel/gas oil		22%	21%	21%	19%	14%	14%
Aviation fuel		21%	20%	20%	19%	13%	13%
Burning Oil		23%	22%	22%	21%	15%	15%
Gasoline		43%	42%	42%	39%	27%	27%

Source: Digest of Energy Statistics UK, Deloitte analysis

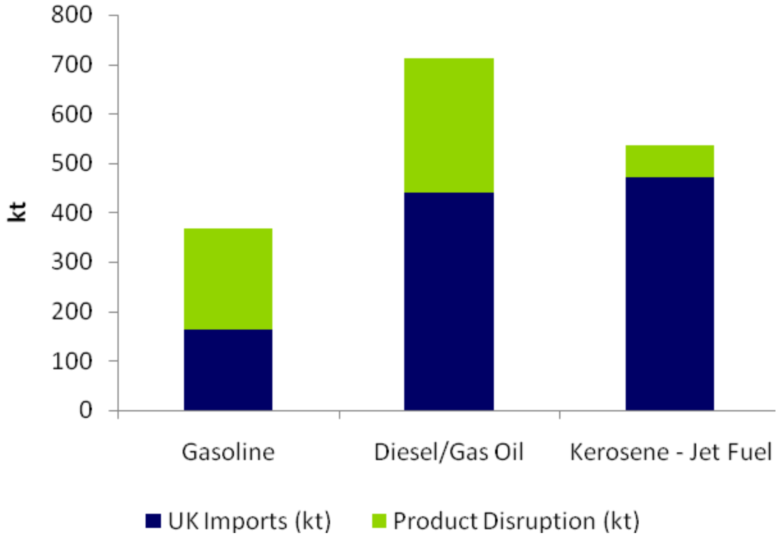
We note that there are unlikely to be constraints in sourcing the additional crude required to increase production at other refineries, as the crude originally intended for Fawley could be diverted to other refineries. There may be potential issues relating to ship size, as the facilities at Fawley are able to accept the biggest tankers currently in operation, namely ULCCs. However, ship-to-ship transfers to a smaller vessel can be used where the facilities at other refineries are inadequate.

Refined product imports

Additional refined product imports could also act to offset a disruption to refinery production. The relatively small scale of this interruption in global terms suggests that it will be possible to access replacement product. However, the handling capacity of UK import terminals may be an issue. Figure 37 shows that product imports would need to increase by 62%, 125% and 14% for diesel/gas oil, gasoline and aviation fuel, respectively, to fully replace lost production. It is likely that existing facilities may not be able to cope with an increase of this magnitude, particularly for gasoline and diesel/gas oil. There may be some ability to temporarily reconfigure the facilities at Fawley to unload finished product rather than crude, although there may be a number of constraints which limit this ability, as discussed in Section 5.8.

The duration of the interruption may also be reduced by alternative product imports. Additional imports sourced from Europe will arrive in approximately five days, which compares to the seven days required for the full refining process.

Figure 37: Comparison: Total Import and Disruption Volume (3 week period) (kt)



Source: IEA, Deloitte Analysis

Diversion of exports

The option of diverting intended product exports may offer further mitigation. In particular, the remaining UK refineries could comfortably replace the volumes of gasoline interrupted by diverting gasoline production which would otherwise have been exported, given the surplus volumes of gasoline exported. This is both in the base refining capacity scenario and under the assumption of the closure of two refineries.

There is, however, only limited scope to divert aviation fuel exports to offset the loss of domestic production. Diverting all aviation fuel exports should be sufficient to offset the loss of domestic production. However, the most significant export destination is Ireland, and diverting these exports is unlikely to be politically feasible. If all but the Irish exports are diverted, there will still be a shortfall of some 2.5kt/day in the low refining case and 2.3kt/day in the base refining case.

Again, the ability to reduce diesel/gas oil exports is far more constrained. This is because relatively low volumes of diesel/gas oil are exported and a proportion of these are likely to be of incorrect quality, as discussed in Section 5.4.

Utilisation of inventory and stocks

Table 37 shows the relative magnitude of the disruption with respect to current stocks within the UK distribution system. It is clear that the current level of stocks exceed the expected product disruption associated with this interruption.

Table 37: Reserve option to mitigate Fawley disruption

Product	Total Disrupted Volume over 3 week period (kt)	Stocks held in the form of product (2008)
Diesel/Gas Oil	271	4,339
Gasoline	204	1,063
Aviation fuel	66	1,116

Source: DECC, Digest of Energy Statistics UK

Net impact of interruption

With UK refining capacity temporarily being reduced by 18%, it is unlikely that the remaining UK refineries would take up the shortfall, in either the low or base scenario. This suggests that alternative product imports will be needed to offset the disruption and eventually replenish stocks. There may be associated import capacity constraints unless Fawley can be temporarily reconfigured to take product rather than crude imports.

Diversion of exports is able to mitigate the gasoline disruption but it is not possible to mitigate diesel/gas oil shortfalls. Similarly, if it not possible to offset the disruption to aviation fuel supplies by diverting exports in the low refining case, even if Irish exports can be diverted. However diverting Irish exports would be sufficient to offset the disruption in the base refining case. Finally, stocks would provide sufficient stocks to cover this interruption.

As the disruption is short-lived, localised to the UK and small on a global scale, the interruption is not expected to have a significant impact beyond the economic boundaries of the UK. As a consequence, no price change is anticipated due to this disruption in either crude or product markets. Furthermore, despite the increase in demand and the stress on supply, oil companies are thought to be reticent to increase prices to ration distribution following a local disruption, due to facing charges of profiteering. As a consequence the pricing mechanism is not fully deployed as a mitigating factor. This is supported by an EIA study on the price impact of refinery interruptions, which indicates that there is generally not a significant price impact[72].

Table 38 summarises the impact of the various mitigation measures available to offset an interruption to the Fawley refinery.

[72] http://www.eia.doe.gov/oiaf/servicerpt/refinery_outages/SROOG200701.pdf

Table 38: impact of mitigations following interruption to Fawley

	Scale	Duration of disruption	Impact on UK	
			Base refining	Low refining
2008 2015 2030	266kb/day	21 days	3.1kt/day of aviation fuel (6-9% of demand) 9.7kt/day of gasoline (21-38% of demand) 12.9kt/day of diesel/gas oil (16-17% of demand)	

Measures to mitigate interruption				
Mitigation	Issues	Time	UK interruption	
			Base refining	Low refining
Sour heavy crude imports	Not applicable as an independent mitigating measure			
Imports of direct replacement grades	Not applicable as an independent mitigating measure			
Increased domestic production	• Limited additional refining capacity given nature of disruption • Likely to be already maximising production of middle distillates • Assume 50% of theoretical spare capacity • Subject to availability of additional sweet light crude	• 1 – 2 days	• 2008: Reduces diesel/gas oil interruption to 10.1 kt/day, aviation fuel to 2.5kt/day and gasoline to 5.5kt/day after 1 – 2 days • 2015/2030: Reduces diesel/gas oil interruption to 10.2 kt/day, aviation fuel to 2.5kt/day and gasoline to 5.6kt/day after 1 – 2 days	• 2008: Reduces diesel/gas oil interruption to 10.4 kt/day, aviation fuel to 2.5kt/day and gasoline to 5.9kt/day after 1 – 2 days • 2015/2030: Reduces diesel/gas oil interruption to 11.1 kt/day, aviation fuel to 2.7kt/day and gasoline to 7.0kt/day after 1 – 2 days
Diversion of crude exports	Not applicable as an independent mitigating measure			
Diversion of product exports	• Substantial exports of gasoline • Limited ability to divert diesel/gas oil exports due to quality issues • Some ability to divert aviation fuel but majority routed to Ireland	• Immediate	• No mitigation for diesel/gas oil • Gasoline fully mitigated • Aviation fuel fully mitigated if all exports diverted, 0.8kt/day shortfall without diverting exports to Ireland.	• No mitigation for diesel/gas oil • Gasoline fully mitigated • Aviation fuel interruption fully mitigated if all exports diverted, 1.4kt/day shortfall without diverting Irish exports
Product imports	• Subject to spare refining capacity • Subject to handling capacity constraints	• 6 to 41 days, depending on source	100% interruption for 5 – 41 days (assuming pre-shock demand)	
Stocks	• Restricted primarily to stocks in product form	• Immediate	No interruption	No interruption

Immediate price impact following interruption
Little price impact expected

Source: Deloitte analysis

6.7 UK primary distribution

Initial disruption

The dedicated aviation fuel terminal at the Bristol Royal Portbury dock receives 1,200kt of kerosene per year, directly discharged into pipeline and storage infrastructure. A three week interruption to the Bristol Aviation Fuel Terminal would disrupt aviation fuel imports of around 70kt, or around 3.3kt per day. Our interruption scenario assumes that the interruption is caused by a shipping accident, thus leading to an immediate disruption in product imports.

In general, import terminals tend to be smaller in scale than refineries. The 70kt of product disrupted in this scenario is only a small proportion of the volume of product that was interrupted in the previous refinery interruption scenario at Fawley. As a consequence, the infrastructural stress resulting from a terminal interruption tends to be less than that resulting from a refinery interruption. Nevertheless, import terminals tend to be more specialised, while refineries produce a range of products. Accordingly, the 70kt BAFT disruption represents a greater volume of disrupted aviation fuel production than in the Fawley scenario. This suggests that though a terminal disruption would be likely to cause less infrastructural stress, the demand repercussions are more focused by product and potentially as severe.

Measures to mitigate interruption

Alternative product imports

The main and most likely mitigation is to attempt to discharge the product at an alternative facility. Diverting the product imports to other aviation fuel import facilities would require a significant increase in utilisation of the alternative facilities. When viewed on a daily average basis, increasing the imports of other terminals by 3.3kt per day represents an 18% increase in imports, which may not be feasible. In particular, there are concerns about onward pipeline transit from some alternative facilities, such as Fawley and Coryton, where the pipelines are known to be highly utilised. Furthermore, pipeline shipping schedules are programmed monthly and there is limited scope for changes due to the importance of product sequencing in order to maintain product quality in multiproduct pipelines. That said, however, there are a number of alternative ingress points which currently appear to have some degree of spare capacity.

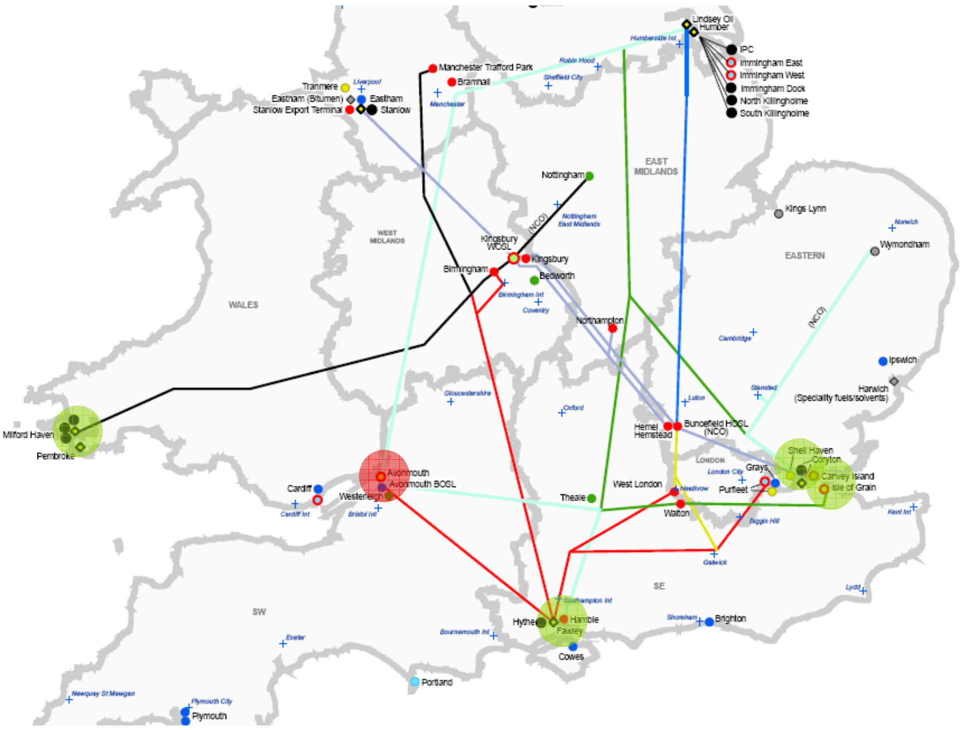
- **Pembroke/Milford Haven refineries**. The Welsh refineries have large docking facilities that can accommodate vessels more than five times the size of the disrupted vessel. With an ingress into the Mainline pipelines, which is not currently heavily utilised, it may be feasible – pipeline shipping schedule permitting – to pipe the aviation fuel to the Kingsbury terminal from where it can be sent to Birmingham airport and other proximate airports.

- **Milford Haven import terminal:** the largest independent storage site in the UK is also maintained at Milford Haven. It has storage capacity of 1,200kt, almost 25% of the UK's independent storage capacity. The facility also has the capacity to take ships of up to 120,000 kt, far in excess of the 70,000kt disrupted kerosene ship. If offloaded here, the aviation fuel could be moved via the Mainline pipeline at Milford Haven as discussed above.

- **Canvey Island:** Canvey Island is another import terminal with large storage capacity. From discussions with industry experts, it is known to have in the region of 100kt of spare capacity. It has pipeline access that was previously used during the Buncefield disruption and would consequently be capable of making delivery of the product. However, it does only have 45,000 kt maximum vessel capacity and so the shipment would need to be lightered[73] before it could be received at the dock. We note that a recent agreement signed between BP and Oikos Storage Limited for the exclusive use of fuel storage facilities at Canvey Island might limit the potential for aviation fuel imports through the facility in future.

In general, however, much of the commercial pipeline system involved in the supply of aviation fuel to Heathrow, Gatwick and Birmingham airports operates close to capacity. This suggests that there may be constraints in pipeline transit from alternative import ports.

Figure 38: Terminal Interruption and Alternative Discharge Points



Source: DECC

Export Diversion

There is only limited scope to divert exports of aviation fuel, as discussed in previous scenarios. Restricting exports to all destinations, including Ireland, will be sufficient to cover the interruption in both base and low refining capacity scenarios, but a product shortfall will still remain if all exports with the exception of those to Ireland are restricted.

[73] Lightering is the process of transferring cargo between vessels of different sizes.

Stocks and inventories

Aviation fuel stocks would be adequate to offset the lost imports, with currently over 1mt of aviation fuel stocks held in the form of product.

Net impact of interruption

It may be possible to offset this disruption by utilising alternative import facilities, subject to location and capacity of the pipeline system. In the low refining capacity scenario, the increased number of import facilities which would result from increased levels of product imports should offer increased import flexibility. In general, increased domestic refining production offers little scope to mitigate this disruption due to the limited ability to increase aviation fuel production and the low levels of aviation fuel exports. Finally, current stock levels are more than adequate to mitigate this disruption

Due to the scale of the interruption it is not expected to affect aviation fuel markets. No physical production has been interrupted at a global market level, and so no market price change is anticipated following this disruption. If the interruption is successfully mitigated using alternative import facilities, no local price impact is expected either.

Table 39 summarises the impact of the various mitigation measures available to offset an interruption to the BAFT facility.

Table 39: impact of mitigations following interruption to BAFT

	Scale	Duration of disruption	Impact on UK	
			Base refining	Low refining
2008 2015 2030	3.3kt/day	21 days	3.3kt/day aviation fuel *(7%-9% of demand)* 3.3kt/day aviation fuel *(6%-8% of demand)* 3.3kt/day aviation fuel *(5%-6% of demand)*	

Measures to mitigate interruption

Mitigation	Issues	Time	UK interruption	
			Base refining	Low refining
Sour heavy crude imports	Not applicable as an independent mitigating measure			
Imports of direct replacement grades	Not applicable as an independent mitigating measure			
Increased domestic production	• Likely to be already maximising production of middle distillates • Subject to availability of additional sweet light crude • Some limited ability to adjust relative yields of diesel/gas oil and aviation fuel, or to replace burning oil production • Assume 50% of theoretical spare capacity	• 1 – 2 days	• 2008: Reduces aviation fuel interruption to 2.5 kt/day after 1 – 2 days • 2015/2030: Reduces aviation fuel interruption to 2.52 kt/day after 1 – 2 days	• 2008: Reduces aviation fuel interruption to 2.5 kt/day after 1 – 2 days • 2015/2030: Reduces aviation fuel interruption to 2.74 kt/day after 1 – 2 days
Diversion of crude exports	Not applicable as an independent mitigating measure			
Diversion of product exports	• 1mt p.a of aviation fuel exports to Ireland (3kt/day) • Further 2.2kt/day unspecified exports • We assume these decrease proportionally with low refining capacity	• Immediate	• 2008/15/30: Removes interruption if all exports can be diverted • 2008/15/30: 1kt/day shortfall if Irish excluded	• 2008/15/30: Removes interruption if all exports can be diverted • 2008/15/30: 1.6kt/day shortfall if Irish excluded
Product imports	• BAFT ship needs a large enough port to discharge or be split • Ability to divert cargoes intended for Rotterdam • Subject to handling and transit capacity constraints	• 1 – 2 days for BAFT ship • 5 to 41 days, depending on source	• No interruption once BAFT ship discharges • Full interruption for 5 – 41 days	• No disruption once BAFT ship discharges • Full interruption for 5 – 41 days
Stocks	• Restricted primarily to stocks in product form • Some stocks may be located in the Netherlands	• Immediate	No interruption	No interruption

Immediate price impact following interruption

Little price impact expected

Source: Deloitte analysis

7 UK refineries and downstream resilience

7.1 Conditions where UK refineries benefit resilience and security of supply

The table below summarises the ability of UK refining capacity to respond to different types of disruptions. It sets out how the exposure to a disruption varies by having more or less refining capacity and the possible benefits in terms of resilience offered by UK refineries.

Table 40: Ability of UK refinery capacity to mitigate different types of interruption

Interruption	UK refinery capacity
Light sweet crude	Exposure increases with scale of UK refining capacity Mitigations ▪ Limited access to alternative crudes due to inflexibility in taking substitute sour crude ▪ Diversion of crude exports possible, but only fully sufficient for lower levels of refining capacity
Refined products only (outside the UK – potentially originally caused by crude interruption)	Exposure reduces with scale of UK refining capacity Mitigations ▪ Dependent on spare capacity / yield structure of UK refineries ▪ Ability to divert product exports

The key conclusion from the supply disruption analysis is that UK refineries increase resilience of the UK market by offering a greater number of options for responding to a supply disruption. However, based on the supply disruptions analysed, the benefits provided by UK refineries are reduced by:

- inflexibility in UK refineries to substitute alternative sourer crude during a light sweet crude interruption;
- limited surplus conversion capacity to increase crude runs and middle distillate production in response to a product disruption;
- reduced ability to match UK product demand given the existing refining yield structure;
- increasing global refining capacity; and
- growth in liquidity and trade of global refined product markets.

Furthermore, the UK is not shown to be any less vulnerable to a domestic interruption due to a refinery outage than to an import terminal outage. A highly utilised pipeline and primary distribution system means that the ability to mitigate an interruption at any ingress point by diverting flows to other points may be constrained.

Nevertheless, there are a number of circumstances where security of supply and resilience is enhanced by having more UK refining capacity.

- **Easy access to light sweet crude**. If there is continued access to light sweet crude following a supply disruption, either by diverting crude exports or by increasing imports from alternative source countries, then the refineries provide increased resilience for the UK market even without further refinery investment.

- **Global refining bottleneck**. In the event of a bottleneck in global refining capacity followed by lack of response to prices of refined product markets, then having UK refining capacity provides greater resilience.

- **International markets are not functioning**. If either crude or product markets cease to function, driven by political intervention to withhold supplies or in the event of a major conflict, then having UK refineries – together with UK crude production – enables the UK to maintain a greater proportion of domestically refined products and enhances security of supply.

7.2 Potential benefit when markets are not functioning

In circumstances in which global oil markets cease to function and economies need to be largely self-sufficient, there is clearly a benefit of having a larger domestic refining base. The probability of this event is remote, but potential catalysts could include war or large-scale and severe international sanctions imposed on the UK.

We provide a brief discussion around the consequences of a full breakdown in international markets, where no refined product is imported to the UK and the UK must be reliant on its own crude production and refining capabilities. The scenario is by necessity stylised and is only intended to provide an indicative estimate of the possible benefit to the UK in a more extreme scenario. An important caveat is that our approach assumes that a product's value is in proportion to its use, a simplifying assumption which could impact the results of our analysis. This is discussed further below.

First, we identified the difference in the production of refined products under a base and low refining scenario. This assumes that refineries increase production to 90% utilisation in both the base and low refinery capacity scenarios in response to the interruption event.

For each product, we then attached to this difference in output the potential economic value in terms of GDP for the UK. This is done in the following steps.

- We begin by calculating UK energy intensity, which is the volume of refined product per unit of economic activity. However, it is difficult to estimate the product intensity for each refined product as we do not have information on the share of GDP attributable to each product.[74]

[74] Data is available on the share of GDP attributable to some products, such as aviation fuel, as this can be linked to the GDP associated with the aviation industry. However, the GDP associated with other products such as gasoline cannot easily be separated out.

Therefore, we have assumed that a product's value is in proportion to its use. Using more refined information on the product intensity of GPD may change these results.

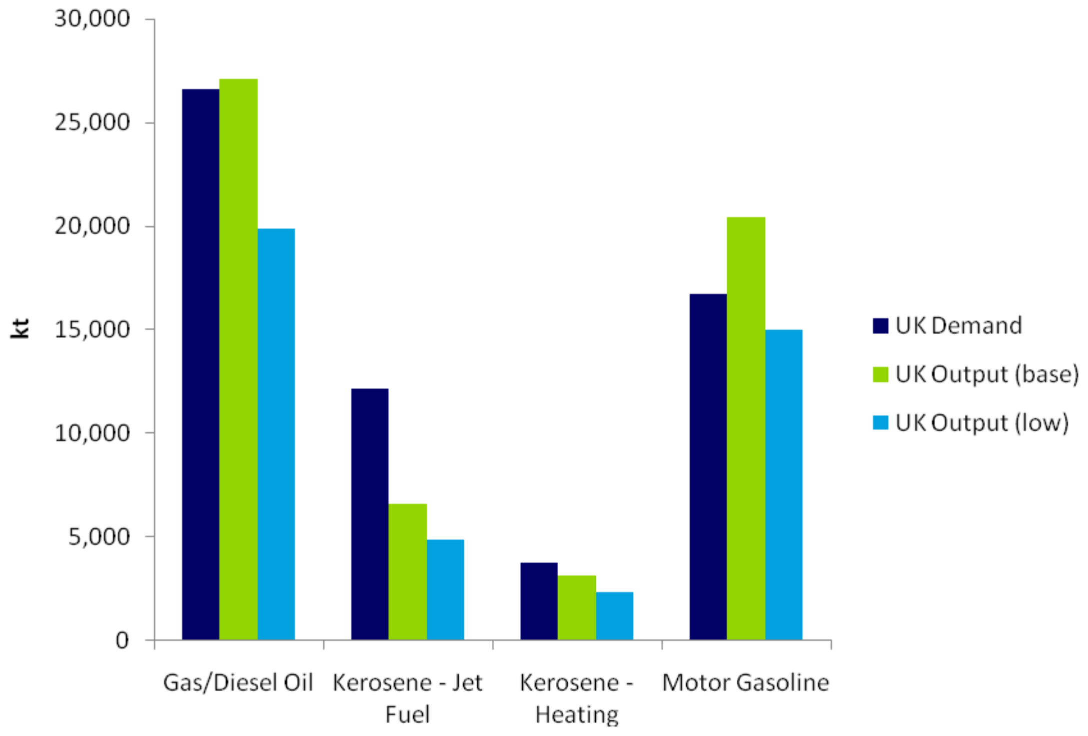
- We assume that the total interruption that occurs is unforeseen and no mitigations (such as stocks) are available, and we also assume that oil product intensity is fixed in the short-term. Consequently a fall in available refined product will restrict economic activity, in proportion to the energy intensity of output.

- We then measure the benefit of having additional refining capacity by calculating the difference in economic loss following an interruption between the base refining capacity scenario and the low refining capacity scenario.

As a simplification, we assume that the North Sea oil production is able to satisfy the throughput requirements of the UK's refineries. Although the UK is a net importer of crude, we assume that the close geographic proximity of Norway and the pipeline distribution links between Norwegian fields and the UK means that the UK may still be able to access crude imports even in a crisis situation.

We calculate the balance between UK refined output and demand, with figures for each product shown below in Figure 39. A shortfall is indicated by the level of UK output being less than the level of UK demand. We have shown UK output both under base and low refining capacity assumptions, to show the increase in the shortfall under low refining capacity assumptions. The net benefit of additional refining capacity in a state of self-reliance is shown in Table 41 below.

Figure 39: Volume balance in a state of self-reliance, by product (kt) (2008)



Source: DUKES; IMF; Deloitte Analysis

Table 41: Economic Impact of self-reliance, by product

	Low Scenario (£bn)	Base Scenario (£bn)	Net benefit of additional capacity (£bn)
Initial GDP (£bn)		£1,446	
Crude Oil Demand (mt)		75,844	
Lost GDP – Diesel/Gas Oil	-£128	£10	£128
Lost GDP – Aviation Fuel	-£139	-£57	£82
Lost GDP – Burning oil	-£27	-£9	£18
Lost GDP –Gasoline	-£33	£87	£33
Lost GDP - Aggregate	**-£328**	**-£67**	**£261**

Source: DUKES; IMF; Deloitte Analysis

Note: The positive values in the Base Scenario column reflect UK output with base refining capacity exceeding UK demand. We have valued such surpluses at zero. For example, the base scenario shows surplus diesel/gasoil production but the net benefit of the additional capacity is valued at £128m, which is the shortfall under the low scenario.

Using the above method and valuing any surpluses at zero, we derive a net estimate of the value of the extra refining capacity to be around £260bn per year. We note that although the economic impact of self-reliance is more severe if there is a larger shortfall between domestic demand and supply, the net benefit of greater refining capacity represents the difference between low and base refining capacity. The delta between the economic impact associated with low and base refining capacity will be similar even under different demand assumptions.

An assessment of global supply disruptions since 1950, shown previously in Figure 26, indicates that a catastrophic breakdown of markets has not occurred in recent history. The assumed likelihood of such an event will determine the expected value of extra refining capacity in a situation of imposed self-sufficiency. The table below shows the expected annual value of additional refining capacity under different assumptions of the likelihood and duration of a catastrophic breakdown of markets.

Table 42: Expected value of additional refining capacity in a state of self-sufficiency

Duration \ Probability of market breakdown	1 in 50 years	1 in 100 years	1 in 150 years
1 month	0.4bn	0.2bn	0.1bn
3 months	1.3bn	0.7bn	0.4bn
6 months	2.6bn	1.3bn	0.9bn
1 year	5.2bn	2.6bn	1.7bn

Source: Deloitte analysis

8 Wider cost benefit analysis

Refineries may provide wider economic benefits in addition to any security of supply or resilience benefits. In this section, we examine some of the key sources of wider economic benefits associated with refineries.

8.1 Employment benefits

The UK oil refining sector currently employs approximately 17,000 people in the UK[75], although some of these are service suppliers such as scaffolders and electricians rather than being directly employed by refineries. The Office of National Statistics (**"ONS"**) recorded 10,000 workers under the category "Manufacture of refined petroleum products".

The employment benefits created by the refinery sector depend on the relative productivity of jobs in the sector. Under the standard Green Book assumptions of full employment, the workers employed in the refining industry would otherwise have alternative employment. The additional employment value created by the refining sector therefore depends on the productivity differential between a refining job and the next best alternative use of that labour. Employees in the sector with technical roles benefit from relatively high wages in comparison to the rest of the manufacturing sector. The level of this wage premium can be valued by comparing the average refining salary with the salaries relating to the next best use of that labour.

Value of a refinery job

Gross wages for refinery workers are not available in the Annual Survey of Hours and Earnings (**"ASHE"**) as the sample size is too small. Instead we use Total Employment Cost, as reported by the ONS, as a proxy for wages. This measure includes wages, as well other items such as pension contribution and benefits in kind. In the "Manufacture of refined petroleum products" grouping, total employment costs are £565m, spread over 10,000 workers. This leads to an estimated average employment cost per technical worker in the sector of £56,500.

Value of the next best alternative job

In the absence of a refining industry, workers will be in alternative employment that may use their labour less productively. Wage levels differ across sectors for a wide variety of reasons. For example, this may be due to differences in human capital, skill and productivity levels in the sector. The highly technical, capital-intensive and specialist operations in the refining process suggests that refining jobs are associated with increased productivity compared with alternative employment options. We undertake sensitivity analysis regarding what this alternative employment might be, to provide a range of estimates of the net impact of the refining sector.

We examine the wage level in three comparator groupings to understand the potential wage premium associated with refining. First, we consider the manufacture of chemicals and chemical

75 UKPIA, Statistical Review 2009 (http://www.ukpia.com/Portals/0/Repository/Documents/Newsletters/UKPIA%20statistical%20Review%202009.pdf)

products. We also consider a range of closely related sectors[76] and finally a much broader category of all manufacturing in the UK.

In Table 43 we compare the refinery employment costs to those of comparator industries. This comparison reveals a clear premium.

Table 43: Overview of refinery employment and next best alternative employment

Employment grouping	Number of Employees	Total Employment Cost (£m)	Average Employment Cost (£m)	Mean Wage (£)	Employment cost differential, (% in parentheses)
Manufacture of refined petroleum products	10,000	£565m	£56,500	N/A	N/A
(1) Manufacture of chemicals and chemical products	126,000	£4,554m	£36,143	£33,127	£20,357 (36%)
(2) Selected comparable industries	219,000	£7,293m	£33,301	£29,358	£23,199 (41%)
(3) Section C (Manufacturing) average	10,396,000	£296,897m	£28,559	£28,456	£28,456 (49%)

Source: ONS - Annual Survey of Hours and Earnings and Annual Business Inquiry

We have also included wage data in Table 43 where it is publically available. The data suggest that average employment cost is an appropriate proxy for average wage data. As can be seen the values are consistently larger than for wages alone, due to the definition of employment cost. As a consequence, our values are expected to slightly overestimate the impact of refining.

Net Employment Impact

The value of refinery employment per worker is estimated to be the difference between the refinery employment cost and the next best alternative. Multiplying this wage premium by the number of workers affected will generate the estimated total value of refinery employment.

We do not estimate a wage premium for indirect workers in the refining sector. As these roles are non-technical, their skills are assumed to be fully transferable. Consequently, the net impact of the employment cost of these individuals is assumed to be zero.

[76] This is a sub-section of 18 manufacturing industries that are thought to be most closely comparable to the manufacture of refined products. These include industries such as the manufacture of industrial gases, dyes, man-made fibres and rubber products.

The net employment impact also depends on what replaces the refinery industry. Without a refinery sector we assume that refineries would be replaced by import terminals as the volume of imports would need to increase to replace domestic production of refined products. The technical workers in an import terminal are assumed to have the same wage premium as technical refinery workers. Data suggests that, regardless of size, the number of employees required to operate an oil terminal is relatively small and in the region of 30 workers. For example the Maasvlakte Oil Terminal in Rotterdam is one of the world's largest terminals with over 23mb of storage[77] and it employs just 40 individuals[78]. We assume two terminals replace each refinery closed; a total of 60 individuals per current refinery site. This is comparable with the Teesside refinery, which employed approximately 80 staff after converting to a terminal, of which 45 are technical staff [79]. Table 44 below shows the estimated employment effect of the refining sector, less the employment benefit from any replacement import terminals.

Table 44: Net employment impact of refineries

Category of worker	Low premium (£m) *(Chemical manufacturing)*	Medium premium (£m) *(Selected manufacturing)*	High premium (£m) *(Total manufacturing*
Technical	£204	£232	£279
Non-technical	£0	£0	£0
Total	**£204**	**£232**	**£279**
Less employment at replacement terminals	-£10	-£11	-£13
Net impact	**£194**	**£221**	**£266**

Source: ONS; Deloitte Analysis

Consequently, the overall net employment benefit that UK refineries are estimated to provide to the UK through employment ranges from £194m to £266m per year.

8.2 Price impact on consumers

UKPIA suggests that UK refineries help to protect UK retail consumers from higher import prices[80]. However, the available data does not appear to support this.

We would expect that final product prices would not vary based on whether the product was imported or domestically produced, for products which are both imported and domestically produced. This is due to the presence of both domestically refined and imported product in the

[77] IEA, Oil Security 2007, http://www.iea.org/textbase/nppdf/free/2007/oil_security.pdf

[78] Facts and Figures on Rotterdam's Oil and Chemical Industry, Port of Rotterdam, http://www.portofrotterdam.com/mmfiles/facts_figures_tcm26-20072.pdf

[79] Industry sources for the number of technical workers. http://www.unitetheunion.com/news__events/2009_archived_press_releases/unite_comment_on_petroplus%E2%80%99_an.aspx

[80] http://www.ukpia.com/Portals/0/Repository/Documents/FINISHED%20VERSION.pdf

same market. As a result, competitive pressures ensure consistent price levels. For example, many supermarket-branded fuel stations are retail distributors of imported refined product[81]. A comparison of average diesel retail prices with those offered by supermarkets suggests that variations are small. Indeed, the data reported by the AA[82] suggests that supermarkets provide slightly lower prices than the market average.

Given consistent final product prices, UK refineries will only protect UK retail consumers from higher prices if the final product price is driven more by the refinery price than by the import price. However, refined product prices (before taxes) are in general benchmarked to a common market price. In the case of the UK and throughout North Western Europe, this is to Amsterdam-Rotterdam-Antwerp (**"ARA"**) prices. Prices are expected to closely follow this benchmark whether the product is sourced through imports or domestic production. That said, we note that the relationship to the benchmark ARA price depends on whether UK refineries produce a net surplus. In product markets where the UK has a net deficit – for example, diesel and aviation fuel – prices will be benchmarked to ARA prices plus transit costs. Where the UK produces a net surplus – for example, for gasoline – prices will be benchmarked to ARA prices less transit costs. This suggests that slightly lower prices for consumers will result for products where UK refining capacity is able to fully satisfy domestic demand. However, the cost of transporting refined product is low relative to the value of the fuel itself[83] so this will only have a marginal impact on consumer prices.

Furthermore, a high-level comparison of domestic refining capacity and product prices at a Europe-wide level does not suggest that a clear relationship exists. In Figure 40 the left axis shows retail prices of diesel and gasoline, excluding taxes. The right axis shows domestic refinery capacity and total domestic demand for refined products. There is no clear relationship that suggests greater domestic refining capacity leads to lower product prices. Neither does the aggregate level of domestic demand that can be met by domestic refineries exhibit a relationship with product prices. For example, Italy has domestic capacity that is greater than domestic demand, but its gasoline and diesel prices are comparatively high. In contrast, German refining capacity is lower than domestic demand but product prices are comparatively low. Moreover, UK prices are not noticeably lower than other European prices (although they are amongst the lowest).

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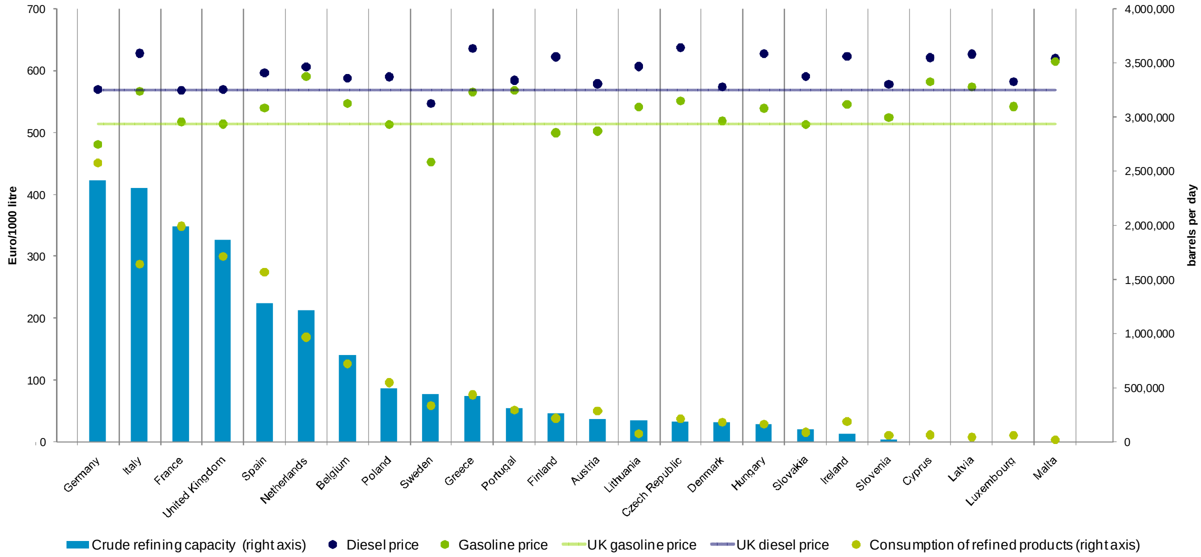
81 WoodMac, UK Downstream Oil Infrastructure,2009

82 http://www.theaa.com/onlinenews/allaboutcars/fuel/2010/january2010.pdf

83 NERA estimates that transport costs have typically represented 4%-8% of the final price for refined product transported from the Middle East to Europe. This would be considerably less for the far shorter journey from Rotterdam to the UK. See NERA (2007), "The competitive context of the European Petroleum Refining Industry in light of the EU ETS".

Figure 40: Product prices and refinery capacity relationship (2008)



Source: EUROSTAT; Oil & Gas Journal
Note: Values are shown before tax

Although this evidence suggests domestic refining does not offer a clear benefit to the UK in terms of end consumer prices, there are potentially economic benefits for the UK from having refineries within the UK's economic borders. Refined product prices incorporate a component for the price of the crude oil input, a component for the operating costs associated with refining, a transit component and finally a component for profit. This is the refining margin. The refining margin has been approximately 7% on average since 2005. Given 2008 UK refinery output we estimate this to be worth approximately £1.2bn.

The stream of annual profit from refineries benefits UK Plc and the UK government through taxation. A share of profit will also accrue to UK shareholders. Without a domestic refining capacity, these benefits may not be captured by the UK. However, few companies that own UK refineries are UK-only ventures. These include INEOS (owner of Grangemouth) and Murco (owner of Milford Haven). The other IOCs that own the majority of UK refineries have an international mix of shareholders. As a consequence, much of the profits derived from these operations do not remain in the UK. Equally, UK shareholders of foreign refineries also share in profits. As a consequence, the physical location of refineries does not necessarily determine the location of where profits flow to.

Furthermore, the Green Book assumption that economic resources are fully employed also applies to capital. There is no evidence to suggest that investment that has occurred in the oil refining sector could not have been alternatively deployed elsewhere. Once differences in risk have been accounted for, the return on this capital is assumed to be similar to the 7% return that the UK refinery sector currently receives. As a consequence, any net benefit from profits from UK refineries and the taxes receipts they produce is expected to be small.

8.3 Petrochemical feedstocks

Petrochemicals are products made primarily from components of petroleum fractions. The industry produces a wide range of products. A small selection includes plastics, solvents, coolants cosmetics and fragrances. According to the UKPIA, the petrochemicals sector has a turnover of £50bn, employment of 214,000 and a trade surplus of £5bn[84].

UKPIA suggests that the UK refining sector plays a major role in the success of the petrochemical industry. This is because outputs from refineries are direct inputs to the industry. The main feedstock that crude refineries provide for the petrochemicals industry is naphtha. Naphtha can be passed through a steam cracker to produce olefins, such as ethylene for production of polyethylene and polystyrene as well as butadiene for the manufacture of synthetic rubber.

As a consequence, locating a petrochemical plant near to a refinery can have a number of benefits for the supply chain of both of these closely intertwined manufacturing operations. This may be in terms of time savings for transferring inputs or greater manufacturing efficiency through shared transport infrastructure. These benefits may lead to lower manufacture and distribution costs. Accordingly, petrochemical plants are often located alongside refineries, or even onsite in the case of Grangemouth, Fawley and Stanlow. This integration allows for time and cost savings by connecting the refinery and petrochemical plant via pipeline.

As well as feedstocks flowing from the refinery to the petrochemical plant, by-products from the petrochemical plant are also returned back to the refinery. Integrated or closely located facilities can provide an efficient delivery method for these “backflows”. For example, fuel gas, fuel oil and pygas are by-products from processing naphtha. Subsequently these by-products can be processed at a refinery and pygas can be blended into gasoline. By having a refinery nearby which allows backflows to be reprocessed, it may be possible to increase the profitability of the petrochemical process. In the case of a stand-alone petrochemical plant, transporting these by-products to alternative refineries would be more expensive, reducing the margin.

However, although these benefits may be valuable, there are examples of operations that do not have the advantage of these benefits. Some European petrochemical plants receive feedstocks via ship and petrochemical plants in Indonesia operate on islands without a refinery. The UK is also an exporter of feedstocks, indicating that sizeable transit distances do not appear to harm the viability of the industry. Furthermore, regardless of current uncertainty about the future of Teesside refinery, SABIC Europe is currently constructing a new low density polyethylene plant in addition to its other petrochemical operations in the area. This suggests that its decision is not dependent on the proximity of a refinery.

There are also a number of alternative sources of feedstocks rather than crude-derived naphtha. Although 52% of global ethylene production is currently derived from naphtha, 30% is manufactured by isolating ethane from natural gas[85]. Major increases in natural gas-fed ethylene production are under construction in the Middle East. Currently, natural gas-produced ethylene

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[84] http://www.ukpia.com/Portals/0/Repository/Documents/FINISHED%20VERSION.pdf

[85] IEA, MTOMR, June 2009

holds a cost advantage over naphtha-produced ethylene. Some petrochemical plants have sold their contractual naphtha deliveries on the spot market so they are able to run the cheaper LPG feedstocks[86]. The IEA suggest that this price difference is expected to continue as excess capacity persists until at least 2014. Due to this price level, many ethylene production facilities are temporarily mothballed and as a consequence, utilisation rates were estimated to be 78% in 2009[87]. Ethylene produced from natural gas also has the benefit of producing lower volumes of by-product. In the event of a petrochemical plant using this feedstock instead, backflows become much less of an issue.

Given these factors, it may be the case that without the UK refining capability, some of the associated petrochemical operations are no longer economically viable. However, a number of broader factors suggest that the proximity of a refinery, although it provides extra value, is not critical to the viability of a petrochemical plant.

8.4 Storage cost

As described in Section 5.9, the UK's membership of the EU and IEA means that a certain level of emergency oil stocks are required to be kept to deal with supply disruptions. The UK currently meets its obligation by placing compulsory requirements on oil companies supplying products to the UK market, which includes refiners and importers. The IEA does not define a specific level of stocks by product. However, under the current EU obligation, countries are required to keep stocks for three separate category groups:

- Category 1 - motor spirit and gasoline-based aviation fuels;
- Category 2 - gas oil, diesel oil, kerosene and kerosene-based aviation fuels; and
- Category 3 - fuel oils.

In mid 2009, stocks held by UK obligated companies exceeded 13 million tonnes across these three categories. This was made up of a mixture of crude/feedstocks (46% once notional yield is taken into account) and refined products (54%) across all categories. In terms of refined products, 46% of stocks are held in other countries on behalf of the UK.[88]

Under the EU directive for emergency stocks, countries are allowed to include crude oil and feedstocks as part of their requirements on the basis of three separate options. The UK has adopted the option whereby refineries estimate the relevant processing losses and product yield factors applicable to their refinery in a current year. This is then applied to the crude oil and feedstocks to obtain an implied volume for each category.

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86 http://www.icis.com/Articles/2009/09/28/9249486/europes-petrochemical-industry-fights-to-survive-capacity-wave-and.html

87 IEA, MTOMR, June 2009

88 Source: EC DIRECTIVE 98/93/EC, stock position at 30 June 2009

In future, the EU will apply a similar system to the IEA for emergency stocks, which will include a requirement for a third of stocks to be held as products. The detail of how this is implemented will depend on each member state, but will need to be linked to the level of consumption for each product. The cost of storing crude is generally lower than for refined products[89] given that:

- Crude is less flammable and requires less complex storage tanks;
- Crude tanks are typically larger and allow for economies of scale in construction; and
- Increasing safety regulations and containment policy following the Buncefield accident have increased the cost of product storage and increased planning issues for new storage sites.

Therefore, under the current arrangements, having a UK refining base supports the way in which the UK can meet its oil stocking obligations by having crude stocks count towards the overall obligation. For this reason, there is a benefit of having part of the UK emergency stocks as crude. If there were fewer UK refineries, it is likely that a higher proportion of emergency stocks would need to be kept as refined products. This would either require additional product storage to be built (if the stocks were to be located in the UK) as typically crude storage tanks cannot simply be used to store refined products, or a higher proportion of product stocks would be kept in storage abroad under bilateral agreements.

For example, if there were no UK refineries, could obligated companies still be able to hold crude stocks as part of their obligation? Under the current arrangements, obligated companies would need to have an agreement with a European refinery (for example in Rotterdam) to process crude oil into products and deliver them to the UK, which would include a given product yield for the relevant refinery. Without such an agreement, obligated companies would need to replace their current UK crude stocks with refined product stocks in the UK and as a result, an additional six million tonnes of storage would be required. Previous work undertaken by Deloitte estimated an average capital cost of £220-260 per tonne of new storage, implying that £1.32bn to £1.56bn of new one-off capital investment cost might be needed to replace crude storage with product storage.

It may be possible to reduce the scale of this investment if companies agreed with the Government that a certain level of crude stocks could be counted towards their obligation. This may be possible as it would reduce the additional investment costs for new storage and crude stocks could be used as part of the UK’s response to international action by the IEA in the event of a supply disruption. Nevertheless, by having fewer or no refineries, holding crude stocks would be of less value compared to holding product stocks.

Therefore there is a wider economic benefit of having UK refineries as it reduces the need for additional investment in refined product storage. Having refineries allows the UK some flexibility to choose whether to store crude or refined product under the proposed EU legislation and a reduction in the refining base may lead to increased product storage, which could be ultimately reflected in higher prices to final consumers.

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89 In its Oil Security Supply Report, 2007, the IEA states that the costs of storage for refined products can be significantly higher than for crude oil.

8.5 Wider spillover effects

Industries that are located near refineries may gain benefits from this proximity. Refineries produce a full range of transport and burning fuels, along with feedstocks and niche products such as bitumen. In contrast terminals are likely to focus on a specialist product or small range of products. This diverse range of outputs allows the refineries to serve a broad range of customers. Consequently, a wide variety of sectors may find it economically valuable to cluster around the refinery to minimise time and cost of accessing fuel inputs. For example, refineries often have petrochemical plants, power plants and heavy industry located nearby. For example, Fawley has a petrochemical plant and a steam power generation station onsite, as well as dedicated pipelines to nearby power stations, while Lindsey refinery has a Combined Heat and Power station onsite. Therefore, the refinery not only acts as a regional hub in the context of the downstream oil distribution network, but it may also act as a hub for other industrial activities. This may create a range of economic benefits including the following.

- **Knowledge spillovers.** Productivity gains can be achieved by allowing the transfer of ideas and the adoption of successful practises and innovative processes. Griliches (1992) suggests innovation can spillover through two channels. First, knowledge spillovers, which are defined as being the situation where research or innovation in one sector is successfully adapted and adopted in another sector. Second, input effects are where the benefits of innovation at a firm which provides inputs to other sectors, are not fully appropriated by the innovative firm. This allows benefits to filter through the supply chain benefiting other firms and industries.

- **Industrial clustering**. By helping in the formation of hub-and-spoke industrial clusters[90], refineries may also encourage the concentration of skilled employment in the area. This will provide a pool of skilled labour for employers and also allow employees to benefit from knowledge sharing through regular interaction and competition with workers in associated firms and sectors. Clustering of industries also provides the opportunity of greater economies of scale for the entire cluster. For example, this may make investment in improved transport and communication links more cost effective and in turn this may lower the cost of distribution and communication.

If a refinery closed and was replaced by an import terminal, we would not necessarily expect that the surrounding industrial cluster would become unviable. Although import terminals generally focus on a smaller range of products, a replacement import terminal would be expected to be able to support the range of refined product needs of an existing industrial cluster given that the market for these products already exists. However, the knowledge spillovers from the refinery would be lost, given that terminal operations are much less complex than those at refineries and require fewer skilled workers.

[90] http://www.eda.gov/PDF/ucluster2004.pdf

8.6 Summary of wider costs and benefits

We summarise the wider economic costs and benefits associated with refineries in Table 45 below. Of these, the most substantial is the additional employment benefit provided by refineries. The additional productivity of a job in the refining industry – as proxied by the difference between the average employment cost in the sector and the average employment cost in various comparator industries – may create additional value of between £190m and £270m per year.

Table 45: Summary table of wider benefits

Channel of impact	Hypothesis	Conclusion
High value employment	• Refineries provide high-wage employment for technically skilled individuals which would be lost without the domestic refining sector	• In the absence of a refining industry, refinery workers would be employed in the next-best alternative role. • Refinery workers are estimated to have a substantial wage premium over comparator industries. • Depending on the comparator industry used this may lead to a UK-wide benefit of £194m to £266m.
Low retail price for consumers	• Domestic refineries keep retail prices lower for consumers than if products were imported than if there was no UK refining sector. • Refining margins from domestic refining benefit UK shareholders and provide valuable taxes to the UK government.	• UK retail prices are generally set in relation to ARA benchmark prices. There do not appear to be savings to consumers where products are both domestically produced and imported. Where a net surplus is produced (gasoline) consumers may benefit through transport cost savings but these are small in proportion to product cost. • Moreover, there does not appear to be a clear relationship between refining capacity and retail prices across Europe. • Refining margins are instead retained by refineries. However, capital would be employed in the next-best alternative investment project in the absence of a refining industry. This would be expected to produce a comparable rate of return and tax receipts.
Valuable feedstocks to other industries	• Domestic refineries support related industries such as the petrochemicals sector by providing inputs.	• Petrochemical plants may benefit from feedstock transit cost savings. Chemical plants also return by-products from their production process for processing and blending at refineries. • However, UK, European and international examples exist of petrochemical plants that are viable and do not have a local or adjoining refinery. • There is substantial over-capacity of feedstock production. Prices are low and no shortages are projected in the medium-run. • Other non-crude feedstocks also exist that have fewer by-products. Using these would reduce the role of refineries if transport costs did rise.
Lower costs of meeting CSO	• Refined product is more expensive to store than crude. Without a domestic refinery industry more stocks would need to be held as product, increasing the cost and requiring new investment in storage	• Refineries provide the option to use crude oil stocks to meet the UK's CSO • A reduction in refinery capacity is likely to lead to a higher proportion of stocks being held as products • Additional storage for product stocks would need to be built in the UK, or stocks would need to be held abroad under bilateral agreements
Wider spillover effects to industry	• As large centres of technical employment, refineries benefit the local industries. • Refineries encourage industries that use their products to cluster nearby, to benefit from lower transport costs and shorter delivery times. This is expected to lead to more interaction between industries	• As sectors, firms and employees cluster, this may generate knowledge spillover benefits, as best practise is adopted and employees interact, sharing ideas. In turn this may increase productivity. • Communication and transport infrastructure may also be more effectively targeted in the area. This will lowering costs and increase efficiency. • This broad and dynamic benefit may be substantial. • While a replacement import terminal should be unable to supply the profile of refined products that the local industry requires, knowledge spillovers from the complex refinery operations would be lost.

Source: Deloitte Analysis

9 Policy implications

The analysis undertaken on oil security of supply and the resilience of the downstream oil sector to supply interruptions sought to address two main questions:

- Should the Government be concerned about the UK becoming more dependent on imported refined oil products together with the associated closure of UK refineries?
- Given the risks and potential impacts of physical supply interruptions what should be the policy response of the Government?

Our key conclusions in response to the first question are set out below in Section 9.1. We then summarise the implications of our analysis in terms of a response from the Government in Section 9.2.

9.1 Key Conclusions

Should the Government be concerned about becoming more import dependant on oil products?

The changing pattern of demand has led to a mismatch between UK refining capacity and demand. This has resulted in a supply-demand imbalance in middle distillates, and in particular for low-sulphur diesel and aviation fuel. This imbalance is expected to increase over the next 10 to 15 years as demand for diesel and aviation fuel grows from current levels as described in Section 2.3. This imbalance is set to be more significant under high demand growth scenarios.

Existing UK refineries are unlikely to address this imbalance given the scale of investment required to build additional conversion capacity to increase yields of middle distillate products (£450m-£700m per refinery for additional hydrocracker capacity). Therefore, the UK is likely to become more import dependent for diesel and aviation fuel over the period to 2020. The extent of import dependency will increase with any further refinery closures.

An increased dependency on imports of refined products may raise concerns relating to resilience and security of supply. However, a number of trends over the last decade are likely to minimise these concerns.

- **Growing trade in oil products** is increasing the liquidity of product markets. This increase in trade has in part grown from the need to address regional imbalances in product supply and demand. The economics of transporting product between regions make trade more favourable than investing in higher refining capacity to meet demand in a particular region.
- A move towards **standardisation of products** will contribute to the depth of certain product markets. 10ppm diesel becoming increasingly standard, and there is only a single grade of aviation fuel used throughout the world.

- **New refining capacity is** being brought online with the intention of **targeting export markets**. For example, large refineries being built in India, Saudi Arabia, Kuwait and Qatar are specifically looking at European markets to export refined products.

- The potential for **spare global refining capacity** in 2015, and possibly beyond, will enhance the ability to deal with supply disruptions. This assumes that prices are allowed to move freely and that refineries respond to these price changes in the event of a disruption.

However, we note that a higher proportion of future refined product imports may come from a small number of countries or regions, in particular from the Middle East and Asia. This is partly due to European refiners being subject to the same financial and competitive pressures as UK refiners, which makes further capacity expansion in Europe unlikely. A reliance on fewer sources may leave the UK more exposed to a disruption from a single source than is currently the case.

Furthermore, there are certain circumstances in which the increased import dependency may raise concerns for the Government in terms of security of supply and resilience. These involve disruption in product markets, which could be driven either by political intervention or a breakdown in trade between major economic regions. This could lead to a sharp reduction in trade and each region becoming self-reliant in terms of refined products, with the effect that Europe may be short on middle distillate refining capacity to meet future expected demand.

Should the Government be worried about the changing patterns of refinery ownership?

Changing ownership in UK refineries in part reflects the reorganisation of portfolios by major oil companies. With excess refining capacity in Europe, together with a mature product market, international oil companies are rationalising their refining capacity in Europe as margins are hit by lower demand and competition from imported products. Many of these companies are instead looking for opportunities in new and growing markets to maximise returns on their investment.

With only a single UK refinery in the top quartile for North West Europe based on gross margins, UK refineries are likely to be considered in plans to rationalise excess refining capacity in North West Europe. For example, Shell announced in August 2009 that it was considering a sale of its Stanlow refinery in the UK, as well as two German refineries at Heide and Harburg.

Given the increased market liquidity and transparency seen over the last decade or so for both crude and product markets, vertically integrated ownership of the supply chain does not necessarily mean better access to crude oil. Therefore, access to supplies is likely to be available to any participant in the market that is willing and able to pay the market price.

However, a number of refineries are owned by independent refinery companies, some of which have high gearing ratios (for example, Petroplus). Typically, vertically integrated oil companies have greater financial capability and are not as highly leveraged in comparison to some independent refiners. In the event of a supply disruption, companies that are highly leveraged may have greater difficulty in accessing additional funds that may be required to purchase products as prices rise during a disruption. Therefore, the financial position of a company may affect the ability to acquire product rapidly at the time of a disruption, which is likely to be an issue both for refiners and for importers.

Should the Government be concerned about refinery closures in the UK?

UK refineries enhance downstream oil resilience by providing a number of additional options to manage a potential supply disruption. This includes diversity in terms of supply sources for crude oil to the UK and the location of crude stocks close to refineries.

However, in the context of the types of interruptions analysed, the contribution of UK refineries to the resilience of the UK downstream oil market is limited by a number of factors. These include:

- a limited ability for UK refineries to use sourer grades of crude and maintain product yields (although there is growing light sweet crude production capacity, sufficient to offset the decline in North Sea production, UK refineries' limited ability to process sourer grades of crude reduces flexibility in the context of an interruption to light sweet crude supplies);

- limited surplus conversion capacity to increase crude runs and middle distillate production in response to a product disruption; and

- reduced ability to match UK product demand, particularly for diesel, given the existing refining yield structure.

Furthermore, the UK is not shown to be any less vulnerable to a domestic interruption due to a refinery outage than to an import terminal outage. A highly utilised pipeline and primary distribution system means that the ability to mitigate an interruption at any ingress point by diverting flows to other points may be constrained.

However, certain circumstances will enhance the value of UK refining capacity in terms of resilience and overall security of supply, subject to the limitations highlighted previously. These are:

- a global refining bottleneck, where there is spare capacity for crude production but constraints for refined products;

- international markets ceasing to function due to political intervention at the time of a disruption; and

- continued access to light sweet crude supplies for UK refineries to maintain product quality and yields.

In summary, the key conclusions from our analysis of the various supply disruption scenarios considered in our work is as follows.

- Given the assumption that **oil markets function sufficiently well** over the period of a disruption, the UK would be able to meet demand for the duration of the interruptions we have examined by a combination of using stocks and accessing global markets. This requires that prices are allowed to move freely to reflect the relative scarcity of the disrupted product and incentivise a market response.

- **Any short term rigidity in the operation of markets could be covered by existing UK emergency stocks** as markets react or rebalance. These rigidities could occur due to the transport time required to source additional supplies or due to the three to six week period required for refiners to adjust their crude input and product output.

- Beyond the timeframe of short term rigidities, **the UK could access the required volumes in the market at the prevailing market price**. The UK should not isolate itself from changes in these price levels as they are an important mechanism to allow for market adjustments in global supply and demand balances.

In the context of wider economic benefits, UK refineries provide additional benefits in three key areas.

- **Employment benefits**. Although refinery workers would be likely to find alternate employment in the absence of the refining sector (under Green Book assumptions of full employment), refineries jobs appear to offer a considerable productivity premium over various comparator industries. This could be up to £270m per year depending on the comparator used.

- **Lower storage costs**. Refineries provide the option to use crude oil stocks to meet the UK's CSO. A reduction in refinery capacity is likely to lead to a higher proportion of stocks being held as products, which is more expensive than storing crude. If all crude stocks needed to be replaced by product stocks, one-off investment costs could be in the region of £1.32bn to £1.56bn. Furthermore, additional storage for product stocks would need to be built in the UK, or stocks would need to be held abroad under bilateral agreements.

- **Wider spillover effects to industry**. Petrochemical plants, power plants and heavy industry tend to locate near to refineries to minimise cost of accessing fuels. This clustering effect may generate knowledge spillover benefits and thereby increase productivity. While there is no reason to expect that a replacement import terminal would be unable to supply the profile of refined products that the local industry cluster requires, knowledge spillovers from the complex operations at the refinery would be lost.

9.2 Policy implications

Based on our key findings, we have identified a number of areas that could enhance resilience and security of supply. We set out below some particular actions and areas for further analysis that the Government may wish to consider further.

How can downstream oil resilience be enhanced?

There are a number of ways in which downstream oil resilience could be enhanced. However, there is clearly a trade-off between the cost of developing additional resilience and the additional benefit delivered in the event of a supply disruption.

Crude supplies

Our work has identified a limitation of current UK refineries given their reduced ability to take on a sourer crude slate to produce refined products. Previously, the UK's position as a net exporter of crude oil meant that this was less of an issue. However, with the decline in production of North

Sea crude, alternative sources are likely to be used in the future, with North/West African (Algeria, Libya, Angola and Nigeria) and Caspian (Kazakhstan) crude likely to replace declining UK and Norwegian crude. There are two main options for enhancing resilience in the event of an interruption to light sweet crude.

First, investment in desulphurisation capacity at UK refineries to enable a sourer crude slate to be used would enhance resilience in the event of a sweet crude supply disruption. However, this is likely to cost between £260m to £440m per refinery to implement and refiners may be reluctant to make this level of investment in the face of low refinery margins, excess refinery capacity in North West Europe and potential opportunities to make higher returns on investments elsewhere.

Second, the UK could build broader and deeper economic and political relationships with the countries exporting light sweet crude oil supplies to the UK. The main future suppliers of light sweet crude to the UK are commercially driven, with oil being sold primarily on a spot basis. Therefore, supplies are unlikely to be secured through long-term contracts and there may be limited scope to secure preferential access to supplies in the event of a disruption. But this may be mitigated to some extent through relationship building.

Access to product supplies

Our analysis has concluded that the liquidity in global oil markets offer the potential to mitigate against product supply disruptions. The move towards standardisation of products has contributed to the liquidity and depth of product markets, and consequently to the alternative volumes which can be accessed in the event of a disruption from a particular source. Downstream oil resilience can therefore be enhanced by ensuring that UK product demand is for standard product specifications so that the UK is able to access the full depth of global product markets.

Storage capacity

Resilience and security of supply could be further enhanced by having more refined products in storage. We note that the level of emergency stocks required to be kept by the UK is expected to increase in light of the UK's declining oil production. This shift in storage requirements could occur as early as 2016. However, this may be expensive, with estimates of £220-£260/tonne for the capital investment required to build new storage facilities. Under the current oil stocking framework, the companies themselves would need to meet this additional level of stocks and would seek to do so at minimum cost. Consequently, a higher proportion of product stocks could be located abroad if companies find it cheaper than building new storage in the UK. This may have an impact on the UK's resilience to local disruptions, or to disruptions which affect access to the stocks held in other countries. The Government should keep the location of stocks under close review.

Managed transition to increased import dependency

There is clearly a transition period that will be undertaken by the UK as it moves towards greater import dependency. This transition will lead to changes in the UK's downstream oil infrastructure, with the potential for some UK refineries to close and the need for additional import infrastructure to accommodate the difference. This could introduce some constraints in supply unless managed appropriately.

- **Increased demand**. The UK represents a relatively large consumer, and a sudden shift from domestic refining capacity to product imports – for example, if several refineries were to close in the space of a few years – could conceivably have a price impact on the global market for refined products. The extent of price increases would depend on the level of spare capacity and the aim should be to manage the transition to avoid large impacts on prices. We note, however, that simultaneous closures are unlikely and the reduction in capacity caused by the closure of a refinery increases margins and makes it less likely that others will close.

- **Jetty facilities**. Product tankers are generally considerably smaller than crude tankers. This means that additional investment in the discharge facilities at jetties may be required in order to accommodate the smaller vessels.

- **Waterway ship handling capacity**. Smaller product ships means that more shipping will be required to service a given amount of UK demand with product imports than with crude imports for domestic production. This has implications for ship handling infrastructure, such as the number of tugs and tug pilots and the monitoring of traffic in waterways.

Ensuring a managed and gradual transition will be important to prevent any supply disruptions due to temporary rigidities in the system.

What are possible actions for government and areas for further work?

Given the above considerations, there are a number of actions that the Government may take to enhance the UK's downstream oil resilience. We have six key recommendations for further work to better understand the required policy response from government.

1. Managing the transition towards great import dependency

The transition towards greater import dependency may be accompanied by logistic and supply constraints, particularly if this happens over a short period of time. The Government can work together with industry to support and facilitate this transition in a number of ways.

- **Notice period for full refinery closure.** This could reduce a potential import capacity bottleneck by avoiding simultaneous refinery closures. A minimum notice period would allow a more managed reduction in refining capacity and ensure that adequate time was available for investment in import capacity to meet increased import volumes in the future. The Government may need to consider short-term financial incentives, such as fiscal incentives, to temporarily retain capacity in the event of multiple prospective closures. These would have to be applied to all existing refining capacity to be equitable.

- **Limiting use of former refinery sites.** A policy consideration could be to reserve the potential use of refinery facilities for product imports. In the event of a refinery closure, the Government could reserve the right to approve the sale of the jetty facilities. These are key facilities which would be required if an import terminal were to replace the refinery. The Government could choose to limit the alternative uses of these facilities given the strategic importance of maintaining the UK's refined product import capacity. This is particularly relevant in light of the possible financial incentives for refinery owners to realise the value of the land by selling to property developers or industrial users. Indeed, the majority of UK refineries decommissioned in the last 30 years have not been converted into major import terminals, but have been developed for alternative uses such as container ports or LNG import facilities. Furthermore, the Government could facilitate the process of transforming a refinery into an import terminal by ensuring that the granting of the required licences and planning permission is expedited.

- **Mothballing of refineries for a limited period.** Further resilience could be obtained by requiring that refineries are mothballed for a limited period after closure, before being fully decommissioned[91]. This would provide the potential for the refinery to be brought back on line if supply and logistical constraints became apparent after closure. This option is only available for a limited period of time – less than one year – as long-term mothballing severely compromises the condition of the refinery. The mothballing of refineries would entail a more managed process of shut-down, together with a programme of on-going checks, to enable capacity to be maintained in a mothballed state. Furthermore, companies may need to maintain key staff over this period which might require financial incentives from Government.

2. Review wider global trends in capacity.

As agreed with DECC, our work has looked at the UK resilience and security of supply, taking global capacity for crude and refinery as a given. Our findings indicate that the UK could become more reliant on global supplies to meet its demands and as such further work on the likely trends in global refining capacity is required. For example, in addition to infrastructural constraints, multiple refinery closures in a relatively short space of time may lead to increased tightness in global markets if new capacity additions elsewhere do not compensate for the increased demand in the required timescales. This will depend on broader global market trends.

Our work has not included a broader analysis of trends in North-West Europe and the rest of the world, and the UK position in the context of these trends. Further work is required to understand the dependencies between the UK's transition towards greater import levels and a possible similar transition across Europe as a whole. This should include an assessment of how the global market will develop in the light of supply/demand trends and the policies of governments.

Work should also be undertaken to examine the potential for bottlenecks in the wider global refining market. Multiple refinery closures in a relatively short space of time may lead to increased tightness in global markets if new capacity additions elsewhere do not compensate for the increased demand in the required timescales. This will depend on broader market trends.

3. Access to markets

We have suggested that downstream oil resilience can be enhanced by ensuring that UK product demand is for standard product specifications, so that the UK is able to access the full depth of global product markets. This implies that Government policy, in as much as it affects product

[91] This would only apply where a sale was not being considered. In many cases, refinery owners will seek to sell a refinery before permanent closure. This often ensures that the shut-down of a refinery is managed and the option for future use is maintained, so that the potential sale price is maximised.

specifications, should be aligned with prevailing policy at least in the EU and possibly with other markets such as the US. The Government should consider the implications of future policy changes on product specifications and work with other bodies to ensure that changes are not made unilaterally. For example, if stretch targets are adopted in the UK under implementation of the Renewable Energy Directive, this might limit the available source market for UK diesel. The base diesel blend required for a diesel containing 15% renewable content is different to the base diesel blend required for a 7% renewable content diesel. It is likely that export refineries can be found which will produce to UK specifications, but a unique UK specification will probably only be available on a term contract basis rather than on the spot market. This considerably increases security of supply risks in the event of a supply interruption from an existing supplier.

This also suggests that incentives might be required to change demand for uniquely UK specifications in the case of increased import dependency. For example, as described in Section 5.6, the UK market for burning oil is relatively unique in Europe. Most domestic burning demand in Europe is for low sulphur gas oil. The growing tendency for UK refiners to divert away from burning oil supply, combined with possible refinery closures, means that the UK may need to source more burning oil from a small global market. The Government should consider incentives – which may include capital or fiscal incentives – to encourage UK domestic consumers to switch to alternative forms of heating such as gas oil heaters, electric heating or ground source heat pumps (which would be more aligned with low carbon goals).

4. Changing storage requirements

The increased volumes of emergency stocks required as a result of the UK's declining oil production, combined with the shift from crude to product stocks as product imports increase and refining capacity is potentially reduced, will require a response from obligated companies. Companies may choose to locate these stocks outside the UK through bi-lateral agreements rather than building new storage in the UK. More work is needed to understand the likely response of obligated companies to increased product storage requirements. This can be taken in the context of whether the existing model will provide the correct incentives for companies to invest in UK storage and the likely impacts of this on regional resilience to supply disruptions.

5. Financeability

Our key conclusions rely on the assumption that oil markets continue to function and that crude and products are available at the prevailing market price. Therefore, one area of potential action outside of the oil market is around financeability and working capital at the time of a supply disruption. More work is required to understand how market participants finance their operations, and the timescales and criteria for accessing commercial credit. The outcome of this may imply that the Government should look at ways of making short-term credit facilities available to companies supplying the UK to ensure that refined products can be purchased at the market price in the event of a supply disruption. This would minimise the potential risk that could be faced by companies if prices were to rise and could not extend their credit facilities to cover working capital requirements.

6. Minimum security of supply arrangements in the event of market breakdown

As agreed with DECC, our work has considered the implications for security of supply of a reduction in refining capacity equivalent to two refineries. Government should also consider what, if any, is the minimum level of refining capacity that should be maintained as insurance against market breakdown. Further work in this area might include an estimate of the baseline level of refining capacity required for the UK to be broadly self-reliant in an emergency situation. This could be developed under a number of scenarios for short-term austerity measures, such as a three day week, with key workers and emergency services operating at current levels. This minimum level of refining would need to be in line with the UK's broader energy strategy and aims to reduce carbon emissions.