COUNTERACT

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TARGETED STUDY EN1 “Estimated Recovery Times for Energy Infrastructures Damaged by Terrorist Attacks”

FINAL REPORT
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I. EXECUTIVE SUMMARY

Security to protect infrastructure components against large scale terrorist attacks, has only recently become an issue of concern in the energy sector. The attacks on the Twin Towers in New York on September 11 in 2001; the London bombings in 2005 or the Madrid bombing in 2004, have demonstrated that the threats expressed by terrorist groups that they will attack the energy infrastructure, should be taken seriously. Security measures in the past have mainly concentrated on ensuring backups are in place to respond to technical failures or on acquiring physical reserves for warranting long-term security of supply.

The consumption of energy will continue to rise, requiring the amounts of energy imported from outside the EU to increase, in order to compensate the decreasing indigenous extraction of fossil fuels. As this trend is not likely to change in the near future, the energy system will continue to be dependent on energy deliveries from sources located outside the European Union, which increases the vulnerable points exposed to terrorist attacks.

This study aims to identify the duration of critical infrastructure component outages after being struck by a terrorist attack. Measures to recover the infrastructure and the supply of energy currently in place are analysed and evaluated to identify where improvements are possible. An overview of the natural gas, oil and electricity systems gave first indications that measures to respond to technical failures or weather hazards together with spares for maintenance purposes would be sufficient to quickly repair any damage pipelines, pylons or transformers. Historically such attacks have taken place within and outside Europe, but the impacts were limited.

Therefore, four hypothetical scenarios are formulated and evaluated using the EU criteria for identifying critical infrastructure components. The scenarios cover infrastructure components from the electricity, natural gas and the oil sectors in which attacks with varying degrees of impacts are simulated.

The scenarios reveal that in all four cases, the energy that is lost due to the attack, can be replaced immediately. The recovery times of the infrastructure components ranged from 3 months to over 3 years depending on the component and the availability of replacements parts. Partly, the damage caused by the attack on the infrastructure component is so grave, that direct measures to try and reduce the recovery times are not feasible. It was also found that the recovery times do not determine the initial impact of the attack and only become relevant, when the energy service of the affected component can no longer be compensated by other means.

Therefore, the recommendations for measures address issues, to ensure that the missing energy from the affected infrastructure component can be supplied over a prolonged period of time and enhance the national and EU wide management of energy crisis situations. This reduces recovery times, because the response processes to the attack are more efficient and EU Member States cooperate to assist each other.
The following report covers the main findings of this study and presents the recommendations in more detail, which have been based on four hypothetical attack scenarios, interviews conducted with representatives from the energy industry and on in-depth research on the energy systems.

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1 INTRODUCTION

1.1 Europe’s Energy Situation

Europe has one of the highest energy consumption rates worldwide, although the per capita rate varies greatly amongst Member States, also reflecting the varying degree of economic development [7]. The economic development on the one hand determines the priority for investments in the energy sector, but equally the economic developments will also give indications as to where the energy consumption is likely to rise the most in the future. The dependence on energy imports is increasing as indigenous production decreasing, although the overall energy consumption rate is and will continue to rise [8; 79; 80].

This means, that the energy system itself and the vulnerabilities of the system are changing. Instead of having to concentrate solely on the EU energy systems to identify potential attack targets, it is necessary to also look beyond the borders of the European Union.

Energy consumption in Europe is expected to grow annually by 1.1 % according to the International Energy Agency (IEA) World Outlook 2007. This would imply, that the dependency would also maintain a constant upward trend, unless new fossil fuel reserves are discovered within Europe. European countries have expressed concerns about these facts, taking the decision to increase the amount of renewable energy resources as well as increasing energy efficiency. The EU has set the goals 20/20/20 to be reached by the year 2020 [20]. This entails, reducing greenhouse gas emissions by 20%, raising the share of renewable energy by 20% and improving energy efficiency by 20%. These goals are important political decisions in combating the impacts of climate change [19], but equally important for reducing the dependency on imported energy resources, which can equally increase indigenous trade among member states to strengthen the economies.
Currently, imported energy resources, mainly crude oil & petroleum products, natural gas and coal make up a large percentage of primary energy consumption. The present economy has been built on these resources and cannot survive without them. Therefore, a sustainable supply is necessary.

Aside from the physical reserves available, which determine the long-term sustainable supply of energy, secure short term supply of energy is subject to various unstable factors. Political conflicts, such as the debate between Russia and the Ukraine [20], which obstructed the supply of energy to Western Europe, and instabilities in the countries from which the resources originate, can have a drastic impact on the availability of fossil energy resources. The energy balance for the EU25 from 2005 [24] illustrated below displays not only the dependence on imported energy resources, but also their dominance in final energy consumption.


It is therefore important to not only analyse possible causes for the short term interruptions of a continuous energy supply within Europe, but to also take into account the resources’ country of origin and the transport route to Europe. Vulnerabilities may be identified to be higher outside the EU, but if known, these can be incorporated when formulating measures to enhance energy security. The energy infrastructure is already subject to numerous interruptions caused by natural hazards or accidents, to which the responsible operators have adapted well and minimized the energy outage times by introducing various measures.

But interruptions can also be caused intentionally through acts of sabotage or terrorist attacks. In and outside Europe, several major incidents have occurred which have highlighted the reality of such threats. On September 11, 2001, passenger planes were hijacked and crashed into the Twin Towers.
Towers in New York, which resulted in over three thousand people killed. In Madrid, Spain on 11 March 2004, a series of bombs were aimed at the commuter train system, killing 191 people. Just over a year later, on 7 July 2005, the public transport system of London was subject to various coordinated bombings killing 52 people. These incidents were not specifically targeted at the energy system, but they illustrate the geographical capabilities of terrorists, which essentially have no limits.

Attacks by terrorists on the energy system themselves have also not been uncommon, as will be illustrated throughout the report. These show that there have been numerous attacks on the various energy systems and its components worldwide, including incidents within Europe. With the aim to scientifically underpin the formulation of policies to enhance energy-supply security specifically aimed at reducing the recovery time after energy outages, this report aims to concentrate on potential terrorist attacks directed at the energy infrastructure, leading to social and economic disruptions in Europe.

This report seeks to establish a background in order to simulate attacks on the energy system, to display the impacts and identify the measures in place enabling the re-establishment energy services. This will be done by looking at historical incidents, caused by natural disasters or by intentional attacks aimed at disrupting the energy infrastructure. The criteria for identifying critical infrastructure suggested by the EU will be analysed and used to evaluate simulated attacks in a comparative and transparent manner. Together, these will establish the basis on which suggestions will be made for EU policies to reduce the recovery times from energy outages caused by intentional attacks carried out by terrorists on energy infrastructure components.
2 METHODOLOGY

The goal of this study is to establish recovery times for energy infrastructure components after terrorist attacks on these have been carried out, leading to social and economic disruptions within Europe. This aims to aid in the formulation of policies within the European Union to ultimately enhance the security of the energy supply. The amounts of people affected by the loss of energy supply and the economic impacts thereupon, are amongst others, criteria used to determine the criticality of an infrastructure component by the EU by analysing various impacts. For the purpose of this study, the criteria are used to analyse the severity of the scenarios. This in turn will lead to the establishment and prioritisation of policies to be implemented, in order to reduce the recovery times of infrastructure components.

The first step will be to establish a background of the three energy systems, electricity, oil and gas, giving a general overview of energy resources, production, transmission and distribution for each system. The energy origin, dependency rate of Europe, processing and transmission types will all play important roles and will be summarized in a single energy flow diagram, the Energy Reference System (RES). This in turn will highlight the various weaknesses and possible points of attack, additionally providing information to establish degrees of severity, but more importantly, provide first insight into what type of alternatives are available.

The system overview will be based on a literature review of information available in journals or newspaper articles, reports and studies. Equally, natural catastrophes and previous incidents will be analysed, providing information to evasive measures currently taken in emergency situations. Further, historic attacks on the energy system and their impacts will be taken into consideration to point out what are the likely targets for terrorists to strike. This is the basis on which scenarios can then be established.

In the second part, the criticality of energy infrastructure components will be measured according to certain indicators and categorized into different priority levels. These indicators, based on those defined for the assessment of critical infrastructure by the European Commission will include the geographical scope, criteria defining severity and finally amount of time for which the effects of the loss of the asset last. Because they evaluate the criticality according to various impacts, the criteria matrix provides a transparent and comparative methodology for assessing the severity of attacks.

The criteria set by the EU will also be analysed to establish if these are detailed enough for evaluating the energy infrastructure criticality, to firstly enhance the applicability of the criteria to the energy sector and to simultaneously aid the process of developing a single tool to be used for the assessment of scenarios or of infrastructure components. The evaluation of the scenarios can provide insight into enhancements, which may be required.

The last part of this report consists of simulating possible attack types in the form of three different scenarios. It should be noted, that the scenarios have been chosen to represent each of the commodities and to illustrate differing impact degrees. These will be discussed in interviews with several representatives of the energy industry in Europe, giving not only insight to the impacts, but
also on the measures and precautions which are currently in place or which are required to enhance the preparedness and reduce the response time to incidents. Finally, recovery time estimates can be made along with recommendations for improvements or further measures for their improvement. This will be formulated into policies, which can be implemented by the EU.
3 CURRENT SITUATION

3.1 Electricity

3.1.1 Overview

Europe’s (EU25) gross electricity production in 2005 was approximately 11,543 PJ (3206 TWh; [24]). The diagram below illustrates the main primary resources which are used for electricity production.

Illustration 3 - Gross Electricity Production by Resource 2005 [24]

This makes clear the interdependency of electricity on other energy systems. Coal and natural gas are two of the resources which are of prime importance to the production of electricity, of which natural gas and petroleum products will be further analysed in a separate part of this report.

Similar to the other energy carriers being analysed in this report, the production of electricity has a high dependency rate on imports. Electricity is to a high degree produced within Europe, but the resources from which electricity is generated is to a large degree imported, leaving only renewable energy resources originating from within the EU. Even uranium deposits are located outside Europe. Canada and Australia are the amongst the largest producers of Uranium, producing 28% and 23% respectively of world output [17]. This indicates that a secure supply of electricity is not only reliant on the indigenous generation and transmission capacities, but also on the reliable delivery of resources required for the generation of electricity. The focus of this section will remain on electricity generation facilities, transmission and distribution and not on the delivery of resources as these will partly be touched upon in other sections of this report.
In 2004, the total electricity generation capacities within Europe amounted approximately 710 GW [79]. Without going into too much detail, electricity can be generated from small scale renewable energy carriers, such as biomass or wind, by large scale renewable energy carriers such as hydro power and through usage of fossil fuels. A further possibility is through the employment of uranium in nuclear power plants, which is the most dominant resource used throughout the European Union, although the degree of usage varies greatly throughout the Member States (see Illustration 22 - EU Member State Dependency Rates on Nuclear Power [27]).

The European electricity transmission system is highly complex, each country having its own operator, varying regulations and different market structures across borders [80]. Due to the high interactions and cross border trades, an EU wide TSO, the Union for the Co-ordination of Transmission of Electricity (UCTE), has been introduced, able to intervene in emergency situations. The electricity transmission system in Europe has developed over the past 50 years, originally designed to ensure mutual stability between member states, which is no longer the only reason for interlinking the systems of countries. Due to market conditions, increasing cross border trade is transforming the European electricity system into a single platform for the transmitting of large quantities across the entire continent [13]. The current system's expansion is limited through strict legal procedures and extensive building times, impacting the installation of additional required capacities and therefore resulting in a system operation closer to system limits.

Further, the fact that electricity cannot be stored, along with the increasing amount of fluctuating power sources being installed, such as wind power plants, increases the significance of regulations on reserves for balancing power fluctuations or system disturbances. The UCTE has thus implemented strict regulations for the availability of such reserves. Exact details to the security measures can be found in the UCTE Operation Handbook, of which the most relevant procedures are briefly explained in the following section 3.1.2. These measures increase the flexibility of the system to cope with an emergency situation by enforcing cross border cooperation.

In order to estimate the impacts of individual components, it is important to elaborate three key component features. The susceptibility to damage, the effect on the power system and finally the availability and time it takes to replace the component [18]. These three factors vary greatly throughout the electricity system. The electricity infrastructure has thus implemented the “N-1” criterion. This ensures that if a single component of the electricity network should fail, such as a transformer, transmission line or a power plant, the stability and therefore functioning of the electricity system is maintained. Some critical infrastructure components will even function according to “N-2”. End users therefore will not be affected should a single component fail. Many individual components, such as pylons, overhead lines or transformers can be replaced with a short amount of time. For example, several kilometres of overhead lines can be replaced within a single day.

The infrastructure has been built to withstand component outages, such as those caused by natural hazards which can often damage electricity infrastructure components. Should multiple component failures occur, the resulting frequency fluctuations lead to blackouts? These can last from several minutes up to several hours depending on the cause and capabilities of the TSOs to re-establish services. Outages can usually be regionally isolated, limiting the impacts of such outages. To restore the supply of electricity, procedures have been agreed upon by TSOs in accordance with UCTE regulations, which forsses a coordinated restart of the system.
When considering the effects of blackouts, all sorts of consumers must be regarded, as the households are effected as well as industries and other servicing sectors. For this purpose, the costs can be split into direct and indirect costs have to be analysed for the three main consumer sectors, residential/households, industrial/commercial and infrastructure/public services. Such calculations result in extensive surveys, of which a large amount of information is difficult to obtain. A study from the Technical University in Vienna, conducted by Dr. Professor Brauner, estimates the costs of various outages within Austria as follows, demonstrating the significance of profound measures.

<table>
<thead>
<tr>
<th>Power loss</th>
<th>Line- Type</th>
<th>Economic Damage</th>
<th>Customers affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,3 MW</td>
<td>0,4 kV</td>
<td>2400 €/hr</td>
<td>300</td>
</tr>
<tr>
<td>20 MW</td>
<td>10-30 kV</td>
<td>0,19 Million €/hr</td>
<td>40000</td>
</tr>
<tr>
<td>250 MW</td>
<td>110 kV</td>
<td>2 Million €/hr</td>
<td>350000</td>
</tr>
<tr>
<td>5000 MW</td>
<td>380 kV</td>
<td>40 Million €/hr</td>
<td>7 Million</td>
</tr>
</tbody>
</table>

3.1.2 Measures in Place

Measures to ensure security of supply are implemented on several different levels. The TSO as well as the distributors have certain responsibilities as do the producers of electricity, ensuring a quick re-establishment of electricity supply should this be lost. All of the measures will not be explicitly mentioned, although a few of the essential measures will be outlined, such as the requirements to the TSOs.

From the generation side, nuclear power and hydro power plants will be looked at more closely. They are important electricity generation facilities in Europe, making it imperative to investigate what safety measures are in place. The backup mechanisms and standards, which are relevant for establishing recovery times of sample electricity generation facilities will be looked at in a system context.

The electricity system is built so that it can withstand single component failures, which are commonly caused by the weather or by unintentional damage by third parties. Such cases can be dealt with well and are routine for the system operators. If there were a single component failure, the system would be operating under the “N-1 criterion” [23] and should therefore not endanger the system security of interconnected operations. Electricity networks and its components should be able to accommodate the additional load or voltage deviations. Operational Network Reserves are maintained by the network operator for this purpose, consisting of “active power reserves”, “reactive power reserves”, an acceptable voltage profile and stability margins amongst others, which would accommodate such contingencies. Should the system further deteriorate beyond N-1, UCTE policy requires TSOs to take any necessary action to stay connected to the synchronous area.
If the system is in danger of experiencing a complete collapse, neighbouring countries shall do everything necessary to aid the affected TSO. TSOs have agreed on points, which are automatically or manually disconnected in the case of frequency drop, overloading or loss of synchronization. In addition, opening of tie lines has been agreed on by neighbouring TSOs should this be required to prevent disconnection.

For any TSO, there are a number of common emergency procedures, which carried out, which rectify most instability. Further, it is stated that in order to manage low frequency, load shedding has to be started automatically. This means that certain lines or electricity consumers are switched off to restore the balance between supply and demand of electricity. Sufficient generation is to be maintained by load shedding, before the unit thresholds of tripping are reached. The order in which customers are disconnected is agreed upon individually. In some cases, customers may have alternative power sources.

Should the frequency rise above 50.2 Hz, power generation units should reduce output or alternatively it is possible to use pump storage power plants to reduce the frequency [13]. If the TSO cannot stabilize their region, then they are disconnected from the entire grid, to avoid spreading of the instabilities.

The effectiveness of such measures can be demonstrated when looking at the statistics for outages in Austria. Excluding the European wide blackout on November 4, the total time that electricity supplies were not available due to unforeseen circumstances, totalled 48 minutes in 2006 [35]. Approximately 47% of these outages were caused by natural hazards. It should be noted, that the overall state of the system plays a major role. Austria does not appear in the listings of major outages throughout Europe by the UCTE [81], indicating the insignificance of these outages, which were all very minor, even though the “N-1” criteria could not be maintained throughout the entire year depending on the load. This shows, that any incidents have been dealt with quickly and effectively. The Diagram below illustrates the reasons for system outages in Austria.

![Diagram showing reasons for system outages in Austria](image-url)
In the case of a system collapse, certain steps are initiated in order to “re-set the network”. So, should blackouts occur, which means that a significant part of the electric grid is without voltage, with total or partial disruption of electricity supply, a complex series of coordinated steps is initiated to bring the affected region back online. A number of power plants are required to have black start capabilities, which means that they can start without an external power supply, in order to supply those power plants that require an external source and thus enabling a coordinated re-start of the entire system. This will allow areas affected by the blackout to gradually be reconnected to the remaining system. These procedures are pre-planned and are coordinated with the UCTE.

The “N-1 criterion” is applied to the remaining infrastructure components, requiring that even the loss of a single power plant would not affect the overall stability of the net. Operating the system at the n-1 criterion comes at a cost. Ensuring that lines do not operate at their full capacity so as to have backup capacities available should a single line fail, also means that less electricity can be transferred from one region to another where prices differentiate. Essentially, more expensive electricity must be used rather than importing more cheap electricity from another region.

Similar to the distribution of nuclear power plants throughout Europe, hydropower, due to geographical differences, is not found in all the member states. Dependency rates on hydropower in some countries are relatively high, Latvia for example reaching 70% and Norway over 95%.

For hydropower plants, such as those located along the Danube by Vienna, there are a certain amount of spares located for the typical maintenance works to be carried out, although larger components must be ordered in advance. The exact details were not revealed to the consultants in the course of the study. What is relevant is that in the event of a larger component failure, these are not readily available on-site nor can these be delivered within short periods (several weeks) of time. Should severe damage to one of the larger components, such as the turbine rotor occur, which would require replacement, repairs could last as long as up to one year. The parts would have to be ordered and in some cases specially made. These are the central components of turbines in hydro power plants of this type, thus unable to function without. It should be noted though, that these power plants have several turbines and the failure of a single turbine would not mean, that electricity production of the entire power plant is halted. Should more than a single turbine be damaged simultaneously, the impacts would be more serious.

A terrorist attack causing severe damage would not only disrupt the production of electricity, but also disrupt transport along the Danube. Such power plants stretch across the entire river and therefore leave no alternatives to ship traffic. A major traffic jam along a primary transport route, amongst which fossil fuels are a common transported good, could be a side effect. When the river is frozen in extreme winters, such traffic jams have been known to last up to several weeks.

A rough estimate shows that over the entire year, with all six turbines functioning, the power plant operates at 66% of the maximum capacity, including maintenance works. Should a single turbine fail, the remaining five would work at 80% of the maximum capacity, to maintain production at the same level.
Most of the electrical power produced for Vienna, comes from thermal power plants [51], which indicates that the city itself may not be greatly affected, but other consumers would be. This of course depends on the reserve capacities of the thermal power plants and additionally the supply priority of consumers.

The total yearly output = 1,000,000 MWh (installed capacity 172 MW) [48]
City of Vienna consumption = 438,687 MWh of electricity produced by hydro

Without going into further detail, the key point resulting from this overview, is that component availability is a critical factor, but spares storage is expensive and storing parts other than maintenance parts is not realistic for such power plants. A well-targeted malicious attack can cause significant outage times. The resulting impacts for this case can be reduced, but operation would be closer to its maximum.

### 3.1.3 Nuclear Power Plants

Even before the terrorist attack on the Twin Towers in the US, on September 11 2001, nuclear power plants have been criticized for their vulnerability to attacks and the hazardous risk, which they pose, especially if they were to be subject to terrorist attacks. Incidents such as the reactor destruction of Chernobyl (1986) or the meltdown of the Three Mile Island (1979) reactor exemplify the various impacts of previous incidents. Additionally, the storage and transport of spent fuel is also a critical factor to be taken into consideration, when analysing the threat of terrorist attacks. In the past, terrorists have shown their determination and ability of striking at exposed structures, striking at centres of civilization. It is thus understandable that nuclear reactors are a much discussed safety issue. Whether the intentions are to interrupt the power supply or to deliberately release radioactive substances, the release of these substances pose the largest threat. For this reason, there are strict regulations on the checks to be carried out after a severe incident, ensuring that the plant is deemed safe, before going back online.

Historically, there have been several attacks on nuclear power plants in the past during times of war, but none so far that have been that have led to the destruction of a nuclear facility [2]. Attacks on nuclear facilities, some of which have occurred in Europe, have not had any serious impacts, but the potential impacts are high. In one specific case, the saboteurs had very accurate information on the plant and its security measures, enabling the attack to be precise and effective, but fortunately not causing any radiation leakage.

Several studies have been conducted to research the safety of nuclear reactors in times of war. Should a nuclear bomb or a conventional 900 Kilogram bomb be dropped on a reactor, the results would be devastating and the reactor would be completely destroyed [2]. But regardless of safety measures of the plant, the only effective measure in such cases is the prevention of the attack.

For similar attacks as those on the World Trade Center (New York) in 2001, studies have shown that nuclear reactors would be more resistant to such attacks than any other civil installations [5]. A study undertaken by the US Electric Power Research Institute (EPRI) concludes, that a plane
A test conducted in 1988 by Sandia National Laboratories [82] in the USA to test the safety of a proposed Japanese Reactor, demonstrated that most of the collision energy goes into the destruction of the airplane itself should it hit a 3.7m thick slab of concrete at 765 km/h [5;17], rather than into the destruction of the power plant.

An alternative attack to interrupt the power plant’s operation may be aimed at transformer units or cooling installations of the power plant so as to provoke a meltdown of the reactor core. With today’s technology, should there be a loss of cooling capabilities, so as to cause a meltdown and a breech of containment, even then a leakage of radioactive materials would be insignificant [5]. Nonetheless, such an incident would still require extensive repairs and outage time of the reactor would be considerable. There are many research programs that address these issues, such as those initiated by the EU or by the IAEA, identifying the risk and at the same time looking at what is required to enhance security measures of nuclear facilities.

Contrary to the findings indicating a low leakage risk [5], a more recently published study on the same topic, would suggest that only modern reactors in Germany, are built to withstand the impact of a military airplane. In Germany, requirements for such security measures were published in 1976, but since then have neglected to include large passenger airplanes. Nuclear power plants such as the German Biblis-A, does not meet the 1976 published requirements and the impact of an airplane would lead to uncertain consequences, where a breach of the radioactive container is not to be fully excluded [50]. When overlapping these results with the age of nuclear reactors in Europe, an assumption can be made to give a rough indication of which power plants may need closer inspection as to the implemented structural security measures.

Illustration 5 - Nuclear Power Plant Construction Start in Europe [54]
The conditions for the attack on a spent nuclear fuel cask are similar. The containers have been tested for various resistances including collisions and fires, which showed that the impacts would publicly not have a significant hazardous impact [17]. But there are controversial arguments about this subject, on which opinions differentiate [83].

This is an important conclusion for the assessment of the degrees of severity and recovery times, as the results from an attack would most probably result in the loss of electricity generation. Of course, extensive test would have to be instigated to ensure that there is no leakage, but it is possible that an attack of a nuclear facility could solely result in the loss of the electricity generation capability. But even this may require substantial test and therefore time to ensure that the plant can be safely restarted.

3.1.4 General Outages

In the past there have been few direct terrorist attacks on electricity infrastructure within Europe. Natural catastrophes or human errors have had the greatest impacts on the system causing disruptions of the electricity supply to numerous amounts of people across Europe. Such an example occurred on November 4th, 2006, when a blackout resulted in large parts of Europe being left without electricity for several hours [13].

Other incidents include major outages in Southern Sweden and Italy in 2003. The systems were subject to a technical failure, causing momentary instability followed by a rapid collapse thereafter. These large-scale outages are rather rare though and statistics indicate the outage times, but the losses of power that occur are significant.

The major outages that have occurred last year recorded by UCTE are displayed in the diagram below. When analysing the causes, it becomes clear that most of the outages can be traced back to “Failure in protection devices or other element” or “False Operation” [81]. The failure of components also causes the longest outage periods. Exceptional conditions, such as storms, are the third highest cause of outages. When looking at the major outages, the rules and guidelines work well, but if the operator makes errors, then the guidelines are less effective.

When further analysing the amount of energy lost, overloads account for nearly 50% of the total amount of energy lost and therefore cause the most significant economic losses. The true cause for these overloads is not apparent from the statistics. Some may result indirectly from third party damage, such as the large blackout in Europe, originating from an incident taking place in Germany. This demonstrates the importance of improved cross border cooperation.
To summarize, much attention needs to be paid to system maintenance, which would reduce the amount of outages and therefore reduce the need to improve recovery times. If the basic prerequisites are in place, then no measures specifically aimed at reducing recovery times will be of use. Therefore, it is also necessary that measures are taken to better train staff and mitigate operation errors. These will act as preventative measures and reduce the risk of unplanned outages. The large variations between countries, leads to the conclusion, that the systems are very different standards and that much attention should be paid to improving the Spanish and Czech electricity system.

### 3.1.5 History of Terrorist Attacks

As previously already mentioned, there have been several attacks within Europe on the electricity infrastructure. The diagram below is a graphic display indicating the spread of terrorism in Europe [51]. This is not specified on the energy sector, but it indicates where historically there have been unrests, many of which were politically motivated. Some of the attacks were targeted at pipelines and other parts of the energy infrastructure, although the attackers were not necessarily organized terrorist groups, such as al-Qaeda.
A statistic from the National Memorial Institute for the Prevention of Terrorism (MIPT) shows that of all the terrorist attacks worldwide on the electricity infrastructure during 1994 and 2004, 65.2% took place in Colombia and 6.7% took place in Spain. Other European countries, which suffered attacks, include France, Sweden and Latvia. The most common elements to be attacked were transmission lines, which was the case in 60% of the total incidents [33]. In Spain, the attacks on the energy infrastructure were predominantly initiated by the Basque Fatherland and Freedom group (ETA) targeting electricity pylons, most of which did not cause any or only slight damage. Other attacks by unknown suspects caused more significant damage by targeting multiple electrical transformers, although the supply outages only lasted several hours during the night.

### 3.1.6 Summary on Electricity

The electricity network throughout the EU is heavily interconnected between Member States. The UCTE has been set up to help in dealing with cross border problems and to deal with the coordination of the entire network in exceptional situations. Measures and criteria have been implemented to improve responsiveness to emergency situations. These have proved very effective, given that the measures can be applied and that the network to which they are applied is well maintained and operated by skilled staff. Long outages are a result of these basic requirements not being fulfilled.

In case of terrorist attacks, the outages should therefore not be significant if only a single target is attacked and if the entire system is in good condition. Measures to reduce any outage times caused by terrorist attacks or other causes, should therefore address the basic requirements to make sure that measures can be implemented.
3.2 Oil

3.2.1 Overview

From the perspective of the European Union, the past but more importantly the current and future balance of oil imports and indigenous production is not favourable. The dependency of the European Union on external supply of oil is far more than would be desirable. 30% of the imported oil into Europe comes from Russia (6), although without considering the actual distribution of the dependency rate, this may at first be misleading. While Western Europe varies in the degree of dependence on Russian imports from complete independence to approximately 35% with the exception of Belgium (~42%), Eastern European countries like Lithuania or Poland, obtain 95% of their oil from Russia.

The members of the Organization of the Petroleum Exporting Countries (OPEC) are currently producing about 40% of the world’s oil, but hold 80% of the proven oil reserves, of which 85% are located in the Middle East. 22% of the world’s oil is in the hands of “state sponsors” of terrorism which are under sanctions from the UN and the USA (1). This displays not only the reliability of Europe on oil imports, but also demonstrates the various vulnerable areas endangering a steady and reliable supply due to the political and geographical location.

Illustration 8 - EU-25 Oil Imports [24]

Political instability in the producing countries is only one factor which could impact the supply of oil. Mid-December 2004, Osama bin Ladin publicly announced al Qaeda’s declaration of a holy war on the oil industry, with their main intention of disrupting the supplies to the U.S. from the Persian Gulf [9].

But al Qaeda is not alone. Terrorist or rebel groups from Sudan, Chechen guerrillas, the separatist rebel group United Liberation Front Asom (ULFA) in India, Kurdish guerrillas belonging to the Kurdistan Workers Party (PKK), Colombian terrorist groups, primarily the Revolutionary Armed
Forces of Colombia (FARC) and the National Liberation Army (ELN) amongst others have in the past all staged attacks on the oil infrastructure around the world [9]. Not all have had the purpose of paralysing the western industrial countries, but the effects of their attacks are reflected in development of the oil prices in recent years. There is a so-called “fear premium” of roughly $10 per barrel of oil [9]. This drives up the costs of energy resulting in that purchasers of oil paying far more than required. A possible way of countering these price increases, is to ensure better and safer transport, which implies the investment of vast sums of money.

The diagram below shows the price development for oil, showing the fluctuations and vulnerability of the price in response to world events. Impacts have been economic developments, wars in oil producing countries and political influences.

![Diagram showing oil price development](image)

**Illustration 9 - Oil Price Development [84] (Prices Adjusted by Quarterly GDP deflator, 2Q 2005 US$)**

A more detailed graph depicting incidents that occurred and showing how these impacted oil prices is given in the appendices. The purpose is to illustrate the interdependencies of world oil markets. This would suggest, that the impacts of an incident taking place in a single European country, may extend beyond just the “direct” affects on the country, but indirectly, the price fluctuations can affect the entire European Union. This would also increase the extent of the impact and therefore possibly affecting recovery times. Measures could not be focused on a single point, but would have to be spread across several regions. Terrorists do not have to strike directly in the country they want to disrupt. They can even achieve the same degree of damage by targeting energy infrastructure on home ground where they additionally enjoy support from their home base [9].

Short term risks within Europe and outside, can have severe impacts on the economies of Europe. Some are more direct, possibly affecting consumers through a supply outage and some may be more indirect, affecting consumers economically, increasing the price of energy. The likelihood of incidents will also vary greatly. Even though an attack on infrastructure outside Europe may be more likely to take place, as will be demonstrated in the following section of the report, should an attack target infrastructure inside the EU, the effects will be greater, more direct and possibly causing greater supply outages rather than purely financial set-backs. Measures and policies can only be enforced within Member States of the European Union, thus making it necessary that these cover both incidents inside and outside of the EU. This leads to the conclusion, that the threats of terrorist attacks on oil infrastructure which take place outside of the EU need to be countered by measures from within.
3.2.2  The Oil Infrastructure

In order to be able to understand the reasoning behind the selected attack strategies in the past and of those potentially in the future, it is vital to take a look at the process chain of oil and the infrastructure enabling the delivery of oil to European countries. The main components of the infrastructure consist of the extraction unit at the source, a means of transport, a point of storage and finally a refining facility. The final products are finally distributed to consumers using various localized means of transport.

The largest portion of proven oil reserves are held outside the EU. Those located within, are concentrated in Norway and in the United Kingdom [8], but of the producing countries, Denmark, Norway, Romania, and the United Kingdom have all been reducing their output, while Italy being the only Country increasing its annual output. Such reserves are not always of relevance though. The UK exports a large portion of its oil to the United States and imports oil for its own consumption. The UK has high quality oil reserves which are more suitable for the US refineries. The UK imports lower grades from other regions [91]. This results in the imports equalling the amount of exports [24]. The oil product portfolio comprising strategic reserves therefore plays an important role within Europe. The reserves may not be readily interchangeable amongst Member States.

As previously mentioned, the major oil reserves important for European consumption are to a large extent located in Russia and the Middle East. For transport within Europe, but also the delivery methods of oil from outside Europe, focus on two means of transportation. Internationally, oil is either transported through pipelines or alternatively onboard tankers.

3.2.2.1  Transport by Pipeline

The transportation routes most commonly used for oil are pipelines and tankers. The diagram below shows the main pipelines within and around the EU. Additionally, key infrastructures indicated in the map, are the ports where oil is delivered by the tankers and the major intersection points of the oil pipelines, as well as oil refineries.
The above map displays the main oil pipelines coming to and within Europe. The black symbols are the oil refineries, a lot of which are noticeably located near and by the coastlines, coinciding with many of the ports receiving oil deliveries from tankers or have been built next to pipelines. The arrows are priority pipelines which have been identified as key supply lines. Such key pipelines, if subject to a terrorist attack, could have major impacts on the supply European oil supply.

There are mandatory requirements for the operators of oil pipelines to ensure that there is a certain amount of spare parts strategically placed, so as to allow repairs to be made to aged or damaged infrastructure. Exact details are limited, but it is clear from past technical failures, natural hazards or attacks on the pipeline infrastructure, that the repair times are relatively short and the impacts on most occasions do not cause an energy outage to customers in Europe.

A review of the components, functionalities and the requirements for oil transportation, and a listing of possible risks and the security measures currently in place shows that on the one hand, the pipelines are very vulnerable items, but should they be damaged, there are suitable systems in place limiting the extent of the damage, reducing the recovery times of the component.
3.2.2.2 Transport by Tankers

International oil transport was originally established on tankers. Oil tankers carry two thirds of the world's oil trade, of which 43 million barrels is crude oil [3]. Tankers are the most efficient, cheap and flexible means of transporting oil world wide, using set maritime routes. The danger, is that along these routes tankers pass straits or chokepoints, which are extremely narrow and prone to piracy or attacks. Although these narrow passageways are not located within Europe, many of the ships passing through the straits are destined for Europe.

Illustration 11 - EU Oil Maritime Transport [87]

The above map shows the main maritime routes of the oil tankers around Europe. Additionally this picture also illustrates areas where oil tanker spills have occurred in the past. The map below shows where the critical passage ways are located around the world. Following is a short description briefly describing the destination and amounts of transit oil as well as the impacts resulting from a closing of these straits.
Illustration 12 - Tanker Passageways through Straits

The narrow straits indicated above are essential for the transport of crude oil worldwide [92].

➢ Bab-el-Mandeb

**Location:** Djibouti, Eritrea, Yemen - Connects Red Sea to Gulf of Aden and Arabian Sea  
**Destined of Oil Exports:** Europe; United States; Asia  
**Oil Flows:** 3 million bbl/day (2004)

A closing of this strait would hinder tankers from reaching the Suez Canal or the Sumed pipeline, forcing ships to pass around the southern tip of Africa. This would dramatically increase the time and therefore the costs of transportation. North bound oil could be diverted over the pipeline passing through Saudi-Arabia, which has a capacity of 4.8 million bbl/day. South bound oil on the other hand would be blocked from reaching its destinations. The “Limburg”, a French oil tanker was attacked there in 2002 by terrorists, which expresses the danger of passing this strait (see 3.2.4).

➢ Bosporus

**Location:** Turkey - Connects Black Sea and Mediterranean Sea  
**Destination of Oil Exports:** Western and Southern Europe  
**Oil Flows:** 3.1 million bbl/day (2004)

5,500 tankers every year pass through this strait and with only a half mile diameter, this is one of the most challenging navigational routes for tankers. It is feared that increasing
demand and there for required transports from this area to Europe would cause considerable navigational problems. An expansion of the PCP Pipeline would be the most efficient expansion of capacities. It is not uncommon that weather conditions influence the passage way, thus causing delays, lasting up to a reported 20 days.

- **Strait of Hormuz**

**Location:** Oman/Iran - Connects the Persian Gulf and the Arabian Sea  
**Destination of Oil Exports:** Japan, United States; Western Europe  
**Oil Flows:** 16.5-17 million bbl/day (2004)

Being the world's most important passage way for international oil transport by sea, the closing of this passage would cause severe disruptions to world markets. Costs would increase drastically for alternative transport routes, should the required capacities even be available. Alternatives include the Petroline, an East-West pipeline through Saudi-Arabia, the IPSA or the Tapline to Lebanon, even though capacities would only reach about 7 million bbl/day. Should political situations improve, additional transport routes could be activated from Iraq to Turkey.

- **Malacca**

**Location:** Malaysia/Singapore - Connects the Indian Ocean with the Pacific Ocean  
**Destination of Oil Exports:** 11.7 million bbd/day (2004)  
**Oil Flows:** Japan, South Korea, China, Pacific Rim countries

The closing or obstruction of this strait would not have any direct effects on the supply of Europe, although world markets may be indirectly affected should other transports need to be diverted to supply oil to Asia.
3.2.2.3 Refining Facilities

Europe’s refining capacities are capable of processing of 25 Million Barrels per day, the largest of which are located in France, Italy, Germany, UK [93]. The above diagram shows a simplified version of the processes and the varying outputs from oil refineries. Unlike any other energy facility, crude oil refineries are central locations at which a single product is processed into a large variety of end products. Oil refineries, as the diagram above shows, process crude oil to produce gases, fuels, heating oils and fuel oils. The processes are heavily interdependent, making the functionality of all these components vital to the overall plant production cycle. (Refineries and their functioning will be looked at more closely in 5.3). They are therefore central facilities which are very susceptible to cascading effects within the refinery, the outage of which would have far reaching impacts.

With regards to recovery times, the decreasing amount of available refining capacities in Europe and the increasing amount of throughput (see diagram below), leads to the conclusion that refineries are ever more operating at their maximum capacities. This makes them a very precious facility within the energy system. The alternatives in the case of an outage would be very limited, further bearing in mind that refineries are each only suitable to processing certain grades of oil.

Illustration 13- Schematics of a typical Refinery [87]
Oil storages are used to increase the security of supply. EU member states are bound by law to hold a certain amount of reserves within EU territory. The required stocks are calculated according to consumption within the previous year and for most EU countries these must be able to last the country for 90 days [88]. The diagram below indicates the amounts of storage and the number of days for which these can supply the particular country. It should be noted that some of the eastern European countries are still in a transitional phase and are thus adapting their storage amounts to meet the requirements of EU law.

The oil stocks are an extremely important backup source for crisis situations [99]. Originally, this contingency plan was formulated by the IEA as precautionary measure against supply shortages.
resulting from the oil shortage in 1973-74 [89]. The goal was to formulate national plans and responsive steps to crisis situations. This is an important mechanism which can contribute to reducing or omitting recovery times. There are however concerns about the quality of the stocks held in Europe and the way in which these are calculated [90].

3.2.3 General Outages

2005, hurricane Katrina damaged or sank 50 of the 4000 oil platforms located off the coast of the US. The result was that nearly all of the oil production was halted, 90 oil platforms were evacuated and wells disconnected for several days. The output was reduced from 1.5 million barrels per day to 650,000 barrels/day, resulting in oil prices to reaching above $70/bbl [29]. An oil rig was torn from its anchoring and drifted downriver into a suspension bridge (image to the left). Total oil shut-ins due to the storm reached 362,796 BOPD equating to 24.19% of the daily oil production in the Gulf of Mexico. For gas production, shut-ins equated to 15%, 1.504 BCFPD, of the daily gas production [46]. The effects echoed all the way to Europe. As the USA panicked and started to import hydrocarbons from Europe, which caused the petrol prices in the UK to jump to £1. Repairs were made, some of which will only be finished in 2010. They total damage estimates average around US$15 – US$17 billion. A single rig needed repairs worth US$135 million and which took two months, additionally adding losses of US$220,000 of earnings per day [47]. Even though this recent occurrence took place in the USA, similar happenings have taken place in Europe. In 1998, a storm caused one of the world’s largest oil-platform to be ripped loose from its anchorage, which rammed a bridge, partially destroying it and further cutting off the water supply linking thousands of people [30]. The North Sea, being one of the main sources for gas and oil for Europe is also subject to storms. February 2007, a storm caused two anchors of an oil platform to be dislodged, thus requiring the 286 employees to be evacuated by Norwegian rescue services [31]. Even more recently, on November 11, a storm in the Black Sea Waters was the cause for further disruptions of the oil supplies, as a tanker carrying 4,800 tones of oil broke spilling some of the oil, causing another ecological disaster.

This demonstrates not only the vulnerability of oil and gas extraction platforms, but also the effects that such incidents have economically and socially. Emergency precautionary procedures are vital to minimizing the negative impacts such incidents can have, economically, ecologically and socially. The impacts reach far beyond just the direct impacts, affecting the transport and food industry as well as many others as a further result. But more importantly, this exemplifies how far the effects can ripple, which will be an important criteria for investigating the impacts of the hypothetical attacks.

3.2.4 History of Terrorist Attacks

Up until of late, the attacks on pipelines were limited to occasional cases of vandalism. Environmental safety and maintenance issues mainly occupied the oil and gas industry.
Since the start of the war in Iraq, there have been more than 450 attacks on oil infrastructure in Iraq (IAGS). Some examples the reports of these attacks are shown below, to give insight into what types of attacks have taken place:

2003

4. June 23 - gas pipeline explosion outside the town of Abidiyah Gaarbiga, near the Syrian border in western Iraq
14. September 8 — attack on pipeline from the Jabout oil field 20 miles (32 km) southeast of Kirkuk to the main pipeline that originates there
33. December 20 - rocket-propelled grenades cause pipeline explosion in the al-Mashahda area 15 miles (24 km) north of Baghdad.

2004

42. March 2 - large explosion on oil pipeline near the northern city of Kirkuk causing a huge fire but no casualties. The blast hit the main oil line leading to the Bayji refinery 125 miles (200 km) north of Baghdad igniting a huge fire police chief Turhan Yussef said. "The explosion happened at 11.15am (0615 AEDT). An explosive device was placed under the pipeline at Al-Riad, 21 miles (35 km) west of Kirkuk," he said.

49. April 8 - mortar round hit natural gas tank and another hit a pipeline at a plant north of Kirkuk operated by the Northern Iraqi Company (NOC) Jumaa Ahmad, head of the fire fighting brigade, said.

These reports continue up until the present day, new attacks being added almost daily [37]. It is estimated that these attacks have cost up to $10 million in oil revenues. This does not include the fact, that a large amount of oil companies have been scared out of the region, which further reduces the long-term investment prospects in the Iraqi oil industry. The fact that the home supply of oil, gas and electricity are at risk so that a secure supply of energy cannot be guaranteed for the population of Iraq, it cannot be expected that the supply to other countries is the first item on the agenda. This therefore causes uncertainty in supplies from this region, possibly a contributing factor to increasing prices world wide. This demonstrates that incidents outside of the European Union are nonetheless effective means of damaging economies of the consuming countries. It also shows that not all affects are imminent. Some of the effects will only be felt in years to come.

The trend can be traced back to increased Islamic terrorism [56]. Statistics suggest a trend which shows a drastic surge in attacks in Columbia as of 1997, which eventually decreased, parallel to which attacks in Pakistan, Turkey, Russia and in Iraq increased. The report points out, that overall, the attacks on oil and gas infrastructure are not significant compared to the total amount of attacks.

A means of transport which has been mentioned for oil, are the tankers travelling across the oceans of the world. An example of an attack, is
the one which took place off the coast of Yemen on October 06, 2002.

In this incident, the tanker Limburg was hit by a torpedo (shown in the picture) carrying 397,000 barrels of oil. The damage to the tanker was about $45 million. In addition, the prices for transport of oil with tankers tripled thereafter, rising from $150,000 to $450,000; cargo is insured separately [38]. Experts expressed concerns, that such vessels may be hijacked and crashed into other vessels or even ports to further disrupt the supply of oil or gas. Similar to the monitoring system for attacks in Iraq, there are also records for maritime incidents. These indicate where there are current dangers for maritime transport. The maps below are examples showing general piracy incidents, which also include amongst others, attacks on oil tankers or even on oil terminals as indicated in the right hand picture.

Illustration 16 - ICC Piracy and Armed Robbery, 2005 [39]

International guidelines for increasing port security have been passed by the United Nations International Maritime Organization, in May 2004, requiring counter terrorist measures to be adopted, including an upgrade of surveillance instruments and increasing patrols. The International Ship and Port Facility Security Code (ISPS) acknowledges these regulations set by the IMO [58]. Without going into too much detail, most of the requirements are re-active security measures. Identification processes of vessels and alert systems are requirements, but the documents also highlight, that each country is required to have its own emergency procedure which must be clear to those operating in those territories.

3.2.5 Effects of Terrorist Attacks

Attacks do not have to be directed at targets within Europe, to impacts Europe. Around the world, oil tankers, of which there are approximately 4000, are vulnerable and can be attacked on the open seas or when passing narrow strait s. In the past these have been subject to piracy attacks as reports from IAGS show [38]. Tankers have been hijacked and their cargo and crew have been held for ransom or sold on the black market. Maritime terrorism caused damages of approximately $16 billion per year. This is comparable to the damage done by hurricane Katrina, although the time frames and the concentration of impacts vary immensely.
A further danger to maritime transport though, could be if boats were to be driven towards one of the coasts, into one of the many refineries located on coastlines. Up until now, the impacts of attacks have been moderate and have not caused prolonged energy outages to any of the consumers within Europe.

Historic terrorist attacks have contributed to rise of oil prices and caused fluctuations. The GDP of Europe has continued to rise and is expected to keep up this trend at around 2% until 2030 [94], indicating that the size of an attack must be much larger than previous attacks, in order to cause severe damage socially and economically. If the true goal of terrorist attacks is to harm the western economies, then the attacks must be made on a larger scale which may also imply that attacks may start to progressively get closer to the European Union.

When trying to identify what the impacts are resulting from an attack on oil infrastructure, catastrophes such as oil spills or natural hazards can be used as means of comparison. Even though the cause is not the same, the impacts are very similar to an attack carried out on a tanker in open waters for example. Apart from the damage to the ship, the loss of cargo and therefore a missing delivery which all result in financial consequences, the additional impacts are also those on the environment. As a result of the oil spill, indirect damages arise. A recent spill due to heavy storm in the Black Sea, resulted in 10 boats being sunken amongst which a tanker lost half of its total 2 million litres of fuel oil. The ship was designer to transport oil on rivers and not withstand such fierce storms [55].

Oil spills can also affect industries, even power generation if the facilities rely on ocean water for cooling purposes. Any ship yards or ports can also be affected by oil spills, but they also impact other smaller industries. Boats catching or even cultivating various marine species can be damaged by the oil, along with the equipment required for these purposes [60]. A lot of seafood could be tainted or contaminated, affecting birds, which are also a common victim of oil slicks. The analysis which have been carried out for these instances rarely focus on economic losses. The main focus is on the environmental damages, so a direct comparison in terms of costs cannot be made.

### 3.2.6 Measures in Place

Since pipelines have been increasingly targeted by terrorists, operators have taken actions to increase preventative measures and the effectiveness of responses to such attacks. These include increasing system redundancy, installation of surveillance equipment, stationing aerial and ground patrols and securing pipeline systems against cyber-security breaches.

When comparing recently announced statistics about oil leaks caused by aged pipelines, the terrorist attacks on pipelines are overshadowed, appearing completely insignificant. The monthly World Finance Review, published by the World Bank every month, suggested that oil pipeline bursts grew from 19,000 in 2002 to 25,000 in 2005 [59]. This is down to countries wanting to export oil while prices are high, through pipes which are over 40 years old and dealing with the leakages rather than halting exports for extensive maintenance work.

As such, to decrease recovery times, ensuring that the remaining system components are fully functioning and in well maintained, would decrease the chances of two simultaneous incidents.
occurring and enable focusing resources on areas more prone to attacks by terrorists. The costs would be high initially, but quicker and more effective reaction to those incidents that are not anticipated, such as terrorist attacks, would help reduce the impacts that such incidents would have.

3.2.7 Summary on Oil

The industries have proven to be well prepared and able to cope with most outages or past supply shortages. Tanker hijacks, attacks on pipelines and refineries, production outages due to extreme weather conditions have all been overcome. Targeted attacks against oil infrastructure components with the intention of damaging western economies and causing supply disruptions are likely to become more intense according to recent threats uttered by terrorist groups. The attacks directed at pipelines leading to Europe and those on tankers have not been effective in reaching the desired goal of terrorists. It is therefore likely, that future attacks will be aimed at targets that cause more heavy disruptions to the European economies.

At the same time, competition throughout the world is becoming intensified and Europe is amongst those competing. This means that the measures in place will need to be enhanced, to maintain and improve the current outage times. The mandatory security reserves are a good start, but to effectively respond to attacks within Europe, further measures are required. Similar to the electricity networks, the pipeline networks need to be better maintained. If capacities need to be increasingly used in a crisis situation, then the entire system is operating closer to its maximum, in which case a further incident possibly caused by poor maintenance would be catastrophic.

Future measures aimed at reducing the impacts of extreme weather hazards are likely to be useful in reducing the impacts of terrorist attacks. Although the targets may be different, the measures to secure European oil supplies against catastrophes such as hurricane Katrina will most likely not focus on individual components. National and international plans efforts are required in dealing with the such colossal impacts.

3.3 Gas

3.3.1 Overview

In the European Union, natural gas is the second most important source of energy after crude oil (including petroleum products). Gross consumption within the EU approximately 19,900 PJ, which equates to 24% of the total energy consumption [24]. Of this, only (8300 PJ) is extracted from sites located within the EU25, which exemplifies the dependency on imports from outside the EU. This is currently not as high as that of oil, but gas is an issue of high relevance in terms of security of supply. The industrial sector, services and households are the three main sectors in Europe for which gas is...
Gas is used in the heating of buildings, for warm water production, as well as for cooling. Gas is also a main resource used in the generation of electricity, which makes up for about a third of its total usage in Europe.

The infrastructure for natural gas shares similarities with that of oil. Most of the gas is imported into Europe, Russia, Algeria and Norway being the key suppliers, although this may alter slightly in the future, if projects such as the Nabucco pipeline linking Turkey and Austria are soon realized. The two main means of transport are the pipeline network, pictured below, and by means of tankers, which transport natural gas in its liquefied form (LNG). Once the gas has arrived at its destination, it can either be stored or directly distributed to customers. Storages are primarily used for daily operations and not as a major backup facility. Unlike oil, gas does not need to be processed in such an extensive process so that it can be used.

Illustration 18 - EU Natural Gas Grid 2005 [27]

3.3.2 The European Gas Network

The Trans-European Gas Network (TEN Gas) in its present state has evolved over the past four decades out of isolated sub-systems of natural gas supply existing in most of the EU25 Member States. Each sub-system was gradually built up at its own pace commensurate with the growing share of natural gas in the national primary energy mix. Each national sub-system represented a fully integrated gas value chain and had a remarkable degree of stability in terms of security of supply as it was controlled by one or few entities that were committed to strict public services obligations in their respective Member States. Those entities were solely responsible for decisions about gas supply contracts and investments in gas transportation and storage to ensure system capacity, reliability and adequacy of gas supplies.
In the absence of market competition gas prices were usually administered in response to the existing cost functions of suppliers. While serving a steadily growing and relatively price-inelastic gas demand, suppliers only had to observe the supply-side economics of their investments into gas infrastructures which they considered necessary for a reliable gas supply. Temporary losses due to over-capacities and redundancies in the provision of gas infrastructures or to operational inefficiencies in certain segments of the gas value chain could easily be recovered by extra profits in other segments by means of monopolistic price adjustments. This practice resulted in relatively high levels of national gas prices per unit of energy in almost all EU Member States as compared to alternative sources of energy (e.g. crude oil) or in comparison to other industrialized countries of the world with liberalized gas markets like the US. In the process of globalisation of world commodity markets, persistently high gas prices began hampering the dynamics and international competitiveness of non-energy sectors in the EU. Gas to power plans lagged behind and private households remained reluctant to change to environmentally friendly gas consumption.

The first EU Internal Gas Market (IGM) Directive 98/30/EC and 55/2003 opened up national gas markets to external competition. It enabled cross-border gas trade by stipulating non-discriminatory Third Party Access (TPA) to the grid at transparent tariffs where transparency means unbundling of the gas price into its commodity and service components. Clearly, the main goal of liberalization policy is to bring down average gas prices by inducing higher cost efficiency in provision of natural gas and operation of gas infrastructures, but the concern of the Regulatory Bodies is also to keep the good records of Security of Supply historically achieved by the Operators.

As a preliminary result of liberalization previously autonomous national networks are now interacting increasing scale in the single EU gas network. A herewith associated risk is the increasing complexity of the now combined system, which requires market participants to adapt to new EU internal circumstances and equally deal with EU exogenous issues. A major disruption would therefore impact a much larger region and therefore require issues to be addressed on an EU wide cooperative basis rather than only on a national basis.

The EU market is on the one hand increasing its competitiveness and the service for end-users, although at the same time there are increased number of risks and complications which can cause instabilities to a much larger system.

3.3.3 LNG Gas Transport

As an alternative means of transportation, gas can be transported in tankers, but only in its liquid form. For this purpose it cooled to temperature to \(-162^\circ\text{C}\), so it condenses into a liquid, reducing its volume by factor 600. The costs for a tanker have decreased over the past, averaging around US$155 million (~€100 million) compared to US$280 million over during the 1980's [44]. The investments into the LNG Project are amongst the most expensive energy projects. Such a project can be split into the following components and they proportion of investments involved in the individual project steps.

- **GAS Production** (gas processing, pipelines) - 15 to 20 percent of costs
- **LNG Plant** (gas treating, liquefaction, LPG, condensate recovery) - 30 to 45 percent of costs
- **LNG Shipping** - 10 to 30 percent of costs
- **Receiving Terminal** (unloading, storage) - 15 to 25 percent of costs

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When LNG arrives at its destination, it needs to be returned to its gas form for which re-gasification units are used. LNG tankers dock and unload the LNG into tanks located at the receiving terminal, which is the processed over several days. This allows for the re-gasification process to run parallel to the docking und un-docking process of the tanker and saves a lot of time.

The costs for a re-gasification terminal with a send out capacity of approximately 3.8-7.7 million tons annually, average from US$200-US$300 million in the United States, but can costs as much as US$2 billion for the newest facilities located in Japan. Of these, the most expensive components are the storage tanks, which make up for approximately one third or half of the total costs for the plant [44].

The potential of igniting and the far reaching impact of attacking LNG infrastructure components has not gone unnoticed and has been announced as potential targets of terrorist attacks by Al-Qaeda [42]. A report focusing on the threat assessment of LNG facilities, underpins the fact that even though the LNG has rather incident free history, there is no reason for LNG to be less of a target of terrorist attacks than any other infrastructure [69].

Principally in its liquid form the gas is not explosive. Should it escape into the atmosphere though, the gas evaporates and quickly creates a highly dangerous cloud. If this cloud is not ignited though, the cloud quickly dissipates. LNG has been transported the past 40 years and have safely logged over 45,000 voyages [42]. Fact is, that research on the real danger of LNG tanker accidents is limited. This is due to the fast technological development of ships with new safety design, reducing the amount of accidents and therefore the amount of data available. Another reason is that the incident size plays a major role and historical data which is available from LNG spills over water is only for minor incidents. Additionally, weather conditions will heavily influence the impact. Temperature and wind strength will determine the speed and the area in which LNG dissipates. The multiple factors make research on the true danger of LNG inflammation very tricky.

A study done by Sandia National Laboratories [43] for the US government, analyses the impacts of several different scenarios. Different size breaching holes were assumed, but not more than two of the tankers three cryogenic chambers were breached. The results of the study show, that thermal hazards would mainly occur within 1600m of the ship, although the near field, 250-500m of a spill, would be most affected. A spill would result in a pool, whose size can range from approximately 150m to several hundred meters. The current, wave size and the wind conditions would alter the effects, but should such a spill ignite; the damage would seriously affect any people or structures in the inner zone. Buildings, tunnels and critical infrastructure such as oil/gas storages or refineries would be affected. Beyond 750m to around 1600m, damage would be low, although injuries and minor property damage would be sustained in this area, varying according to circumstances. The table below identifies various types of causes and effects, categorizing the impacts.
### Potential Impact on Public Safety

<table>
<thead>
<tr>
<th>Event</th>
<th>Potential Ship Damage and Spill</th>
<th>Potential Hazard</th>
<th>Potential Impact on Public Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>High</td>
</tr>
<tr>
<td><strong>Collisions: Low Speed</strong></td>
<td>Minor Ship Damage; no Spill</td>
<td>Minor Ship Damage</td>
<td>None</td>
</tr>
<tr>
<td><strong>Collisions: High Speed</strong></td>
<td>LNG cargo tank breach and small - medium spill</td>
<td>Damage to ship and small fire</td>
<td>~ 250m</td>
</tr>
<tr>
<td><strong>Grounding: &lt;3m high object</strong></td>
<td>Minor ship damage; no spill</td>
<td>Minor ship damage</td>
<td>None</td>
</tr>
<tr>
<td><strong>International Breach</strong></td>
<td>Intentional breach and medium to large spill</td>
<td>Damage to ship and large fire</td>
<td>~ 500m</td>
</tr>
<tr>
<td></td>
<td>Intentional; large release of LNG</td>
<td>Damage to ship and large fire</td>
<td>~ 500m</td>
</tr>
<tr>
<td></td>
<td>Vapour Cloud dispersion with late ignite</td>
<td>~ 500m</td>
<td>&gt; 1600m</td>
</tr>
</tbody>
</table>

**Illustration 19 - LNG Tanker Breaches and Spills [43]**

The analysis shows, that high and medium impact scenarios cause significant damage to structures. The impacts will primarily affect the tanker itself, but additionally, should the tanker be close to structures while loading or unloading at a harbour or possibly when passing through a strait (see 3.2.2.2), the damage to these can be critical. This would imply, that in the planning of an LNG terminal, the extraction or re-gasification plant and any further buildings should be located a minimum of 2 kilometres from the actual docking station to minimize the damage of such a possible incident. The worst case scenario would then be only affected the docking facility and the tanker itself.

In Boston, USA for example, when an LNG tanker arrives, all flights are halted and restricted from passing over the port for fear of a terrorist attack [41]. Tankers entering ports are escorted by the coast guard and a safety perimeter is set up, but it is still not clear what happens when the perimeter is breached.

LNG is currently highly in demand which is confirmed by the building trend. Fourteen terminals currently exist in Europe. There are further six terminals currently under construction in Europe and proposals for another 27 have been made. This makes the evaluation of LNG critical, to identify how best to minimize the impacts and therefore the recovery times if a terminal should be attacked. The results can then be proactively fed into the proposals currently being made and
would save future re-investments in other protective measures when the new terminals are already completed.

### 3.3.4 Gas Storage

Gas storage facilities in Europe are used mainly to balance fluctuations in demand, which are often a result of altering weather conditions. Gas storages also offer improved flexibility for transmission and distribution, functioning to balance the inequalities of winter and summer demand. Storages are also used to enhance the position of traders on the market. Finally, gas storages are a security measure against supply shortages, although this is not uniform amongst EU member states. The table below shows the storage capacities relative to the annual consumption, which illustrates the vast differences in availability of storage capacities. Some European countries, such as Finland, Ireland or Sweden, have no storage capacities at all. A shortage of supply would therefore have very different impacts across Europe.

![Illustration 20 - Selected EU Storage Capacity Relative to Yearly Cons (in %)]

Nature provides supreme underground gas storage sites. Depleted natural gas sites, which are concentrated in Europe, are ideal for storage purposes and do not require costly constructions. It should be noted, that the consumption of gas is due to high seasonal fluctuations, with high demand throughout the winter and low demand throughout the summer. The delivery of gas from around the world is constant all year round and does not vary considerably. To compensate for lacking transport capacities in the winter, storages are emptied this period and filled during the summer period.
This is relevant, since when analysing the impacts for any given incident, the impacts will vary considerably depending on the time of year. During the summer, the gas available in the storage facilities to compensate any losses will be much higher than during the winter period, thus resulting in additional alternatives being required throughout the winter period.

### 3.3.5 Measures in Place

By law, the member states are required to provide security of supply for household customers in certain situations as described below:

- a partial disruption of national gas supplies during a period to be determined by Member States taking into account national circumstances;
- extremely cold temperatures during a nationally determined peak period;
- periods of exceptionally high gas demand during the coldest weather periods statistically occurring every 20 years;

Industrial consumers are exempt from this regulation and therefore are only protected from shortage of supply, should individual member states wish to do so [22]. In the event of a major supply disruption, a European Gas Coordination Group has been set up which is responsible for coordinating the security of supply. It is not clear though what authority the Gas Coordination Group has. In Austria for example, the emergency procedure is clear, but decisions are taken by the Federal Ministry of Economics, so a national basis.

An overview on how backup scenarios are handled in Austria on the scenario types and the backup possibilities for various contingencies also include the case of terrorist attacks, which is of prime importance for the purpose of assessing recovery times. But these plans are limited to Austria and there are no requirements for uniform procedures of this sort throughout the European Union.

### 3.3.6 Summary on Gas

The overview of the gas market and the energy flow has highlighted some key issues which give insights required to better understand the possibilities and requirements for reducing outage times. Looking at the RES it is clear that the entire total flow is limited to a few extraction and transport methods, little processing and limited variations in the types of final consumption. On the other hand, it makes up a large part of the total primary energy mix, of which LNG is becoming increasingly important as means of transport. From these factors it can be concluded that the measures which are introduced to decrease outage times, cannot rely on alternative transport routes, sources or even processing facilities.
It has also become clear, that vulnerabilities along the gas process chain can be found within and outside of Europe. Terrorist attacks both inside and outside Europe will impact Europe, due to its high degree of dependency on imports. Depending on where the attack takes place outside Europe, the impacts will vary regionally and extent will also differ within Europe. The main advantage is, that specific regions within Europe, rely on gas imports of different countries outside Europe. This means, that if there is a shortage of gas coming from Russia for example, partial compensation of the deliveries can be achieved by increasing imports from the North Sea area. This demands a high degree of international cooperation, and is unlikely to function smoothly without intervention from the European Union.

Lastly, a main advantage is the storage possibility of gas. There are gas storage facilities spread throughout Europe differing in capacity. Those countries which do not have natural storage facilities, alternatively use LNG storage or build required storage facilities. Currently there are no uniform regulations across the EU which make gas security storages mandatory nor are there definitive crisis management plans on a international, national or even on a corporate level.

3.4 Cyber Threats

Cyber threats have been included in the report, to demonstrate that physical infrastructure components are not only subject to physical attacks. This is to say, that to cause an outage of an infrastructure component, the component does not necessarily have to be exposed to physical damage. Attacking the IT systems which are used to control or monitor the infrastructure components are just as effective and currently a major issue that needs to be addressed.

In January 2008, the CIA stated that there were several cyber attacks which have taken place worldwide, causing widespread blackouts [82; 83]. IT systems are integrated throughout the entire energy system and are a commonly used as backup features against technical failures. Supervisory Control and Data Acquisition (SCADA) systems are used to control and monitor networks. IT systems enable the unmanned operation of power plants of various types, only controlled remotely via a central control station. They are also used for measurement purposes, data which is then used for accounting purposes for example. The energy infrastructure also uses IT systems in daily operational process, for example for nominations or for personnel access control into facilities. These are only a few examples, nevertheless demonstrating the broad spectrum of IT services and their central role as part of the energy infrastructure. Should these services not be available as a result of cyber attacks, the impacts can be very similar to those resulting from a physical attack on the infrastructure component?

Cyber attacks have developed from harmless intrusions into a system to well planned and targeted attacks. The intentions behind such an attack focus mainly on inflicting on damage to economies by causing a system outage or they are used to obtain personal financial benefits. The system of IT systems complexity has been drastically increased over the past few years. Due to the liberalization process, mergers or company separations have caused systems to become increasingly complex. SCADA systems have become increasingly integrated as standardized systems into corporate networks and are therefore exposed to numerous threats, as before these operated as isolated systems.
The differences between IT systems in the energy infrastructure and standard IT systems elsewhere, increase the complexity of implementing security measures. Antivirus systems are only used with care, a danger of course being that updates are required from an outside connection. The life time of the system overall can be four fold that of the average turnaround period for IT systems within other companies today, ranging from 5-20 years. The focus has been on physical security of components and ensuring 100% availability of the system. Patches and updates are therefore very rarely implemented, as the system vendors will not give any guarantee if foreign systems or applications are introduced. Amongst others, these are characteristics which make it difficult for security systems to be introduced, but solutions to overcome these are available.

The chief problem which obstructs the implementation of security measures in IT systems to reduce the threat posed by cyber attacks is awareness. The real potential is neither understood nor addressed, even though there are several cases, where attacks are acknowledged. There is a case, where a utility has identified a problem in the IT system, which turned out to be caused by a virus. They problem was analysed and a solution was provided, but since several months, hasn’t been implemented. (Due to confidentiality reasons, the names of the company cannot be revealed). This is due to the fact that the decision maker does not understand the problem at hand and therefore will not be held responsible for investments made. The consequences if the virus is allowed to spread are not fully understood. Currently it is only a potential problem and has not caused any damage, so there is not need to react. This example demonstrates that there is a clear lack of understanding and willingness to address these issues.

With IT systems and vulnerabilities very high in the energy sector, a few basic steps are required which can effectively reduce the risk. The first step which mainly addresses the decision makers within companies is raising awareness. It was clear that this barrier can be overcome and has been clearly rejected in the past because IT systems are not the top priority of the executive level managers. Theoretically, successful attacks can cause severe economic losses and also heavily damage the reputation of the company. This top-down approach is required to engage the process of proactively dealing with cyber security. Once the decision has been taken to implement the system, monitoring methods can be initiated to firstly identify what and where the risks are and at a later point in time, provide monitoring for the measures introduced. The implementation can be overseen and coordinated by a task force, who are dedicated to the initial implementation and thereafter the control and update of the security systems, which should be defined as a process.

This concept is not unique for the energy sector and interesting models and process have been developed for other industries and companies, which are equally applicable to the energy sector. Pioneering steps have been taken by the credit card industry. For this sector, there have also been standards and norms introduced something which is also missing in the energy sector with respect to security of IT systems against cyber attacks.

In conclusion, the threat with which the energy sector is confronted is great and there are numerous examples of incidents, which have not been publicly revealed. Recovery times are in these cases affected by the decision making process. The solutions are available today from companies such IBM, Cisco, Symantec or numerous other firms. On the other hand, cyber attacks are a recent, but rapid development and the security issues have only really been intensively addressed over the past 4-5 years. Therefore, it is possible to allow for the process to develop reactively or process can be initiated by regulatory or governmental bodies to address these issues.
4 DEFINING PRIORITIES

In order to define and evaluate attack scenarios, criteria must be identified on which this can be done. In the green paper of critical infrastructure, it is suggested that factors which determine the degree of criticality of scenarios, include capabilities, risks and vulnerabilities, the likelihood of such occurrences happening, as well as the severity. A 7€ million budget was allocated to enhance prevention, the preparedness against and response to terrorist attacks on critical infrastructure. Two thirds of the budget is allocated to trans-national impacts from terrorist attacks [32]. Essentially, priorities to measures taken are allocated to those threats inflicting the greatest damage. According to the EU, impact is defined by three main characteristics: the scope; the severity; and the effects of time. The scope would refer to the geographical area affected by the incident (international, national, regional or local. On a similar basis, criteria such as public effects, economic, environmental, interdependency, political effects and psychological effects need to be analysed when identifying the degree of severity. The element of time is the last aspect which needs be looked at, which can vary anywhere from immediate, to 24-48 hours to on or several weeks. Looking at all these categories and varying impacts, a criteria matrix can be formulated (see Annex) which illustrates the extent of the impacts and the threat which such a scenario poses.

An additional criteria point already mentioned in the assessment of electricity infrastructure components (see 3.1.1) should be carried over to the remaining energy systems. The components’ susceptibility is an important factor that must be taken into the equation, as the location and access to the components plays an important role when analysing the occurrence of a terrorist attack. This translates into the likelihood of an attack even taking place. This is hard specifying, but risk analysis methods would permit the likelihood to be determined as a percentage.

The EU classifies four different categories, used to identify critical infrastructure. The matrix columns have various points allocated to them ranging from 1-4. Should the total number of points exceed 10 then the infrastructure can be identified as being “critical”. Additionally it is required that the scenario affects at least two member states.
4.1 Analysis of Critical Infrastructure Criteria Matrix

The matrix which has been compiled has been compiled on the basis of official EU documents [62]. In the current state, the matrix is used for identifying critical infrastructure in all sectors, not just the energy sector. This means that critical infrastructure from the transportation sector can be evaluated using these set of criteria. The effectiveness of this method is questionable, as the individual points can be interpreted differently by the various sectors. On EU level, the infrastructure component is only critical when several countries are affected, being EU Critical Infrastructure components. Otherwise, the components may only be critical on a national level.

The more precise definitions to each of the individual points listed within the matrix, are currently being elaborated by the EU, a final version due to be released beginning of the summer, 2008. The document which is currently available gives insight into some of the approaches being taken, although these are due to be reviewed according to the EU. Further, the EU is also due to specify the criteria given in the matrix above, for each of the individual energy sector commodities. It is apparent, that this may still not be enough, due variations between countries’ energy systems, a point raised in the discussions with Otto Musilek (see Error! Reference source not found.) and with the GIE Study Group (see Interview & Presentation 5: GIE).
Lastly, the EU states that if sufficient arguments and evidence is available, can argue that any of the infrastructure can be identified as being critical and vice-versa. This is to say, that the matrix can be subjectively modified to suite the needs of the owners or those of the Member States. This is the most critical point, which supersedes the criteria and questions the methods viability. As the final version of the criteria and process has not yet been published, this would be an issue to consider.

The scope, the severity and the time are the three main factors used to determine the criticality of an infrastructure component. It should be noted, that the geographic region and the time horizon may vary according to the issue to which it is related and therefore may be difficult to determine. The scenarios will be evaluated according to all three factors, but not on a cross-sector basis as suggested by the EU. This is to say, impact figures will be energy sector specific. Without going into too much detail, death tolls for example in the transport sector will vary greatly to those involved in the energy sector.

Those aspects which cannot be quantified (Environment, Interdependency, Political Effects and Psychological effects), will be evaluated according to past incidents, interviewee opinions and comparable examples.

Differentiations will be made to try and distinguish between direct and indirect impacts. Direct impacts are all those which are caused to the facility and at the point of time of the attack. Indirect impacts are all those, which are a result of the infrastructure not operating. This is to ensure, that there is a differentiation between the impacts which can be quantified and those which can only be estimated or can be subjectively interpreted.

The objective of implementing this criteria is twofold. On the one hand it is used so that there is a comparative and transparent tool used to determine the impacts of different scenarios. It should be noted, that the certain impacts evaluations will be made with worst case scenarios in the energy sector. The impacts of the different scenarios will then be used to determine the recovery times. On the other hand, the criteria will be implemented and tested for its applicability. The feedback derived from its application can then be used to enhance the work in the EPCIP.

In the following section the matrix has been split into the 3 different categories, ranging from low, medium to high damage. The first section of the matrix has been omitted because this is the lowest case. If the criteria is not applicable, then this is applied in the first section, the lowest degree of severity.
### 4.2 Low Impact Assessment

<table>
<thead>
<tr>
<th>Impact Assessment</th>
<th>Degree</th>
<th>Scope</th>
<th>Geographical Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>Regional</td>
<td></td>
</tr>
<tr>
<td>Severity</td>
<td>Minimal</td>
<td>Public</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Economic</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Environment</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interdependency</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Political Effects</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Psychological Effects</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>24-48 Hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>loss of element</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Terrorist attacks on infrastructure components with low impact affect only a limited area, in this case regional. The recovery of the element and service is limited to one to two days. The public is only slightly affected and the economic damages are limited to replacement costs of the component and the lost MW/bbl/m³. When evaluating public impacts, which also includes the total casualties, these will be made referencing worst case scenarios in the energy sector. If they were compared to worst case scenarios in the transport sector, each of the following scenarios would have only a “minimal” impact, which would falsify the results.

The cascading affects on other components is also minimal, as these can most likely not be avoided using current measures which are in place. Politically and psychologically, the incident does not cause panic or international uproars. People and politicians may become aware, but there is no significant reaction to the incident. The time period for which the element is lost ranges from 24-48 hours.
4.3 Medium

<table>
<thead>
<tr>
<th>Impact Assessment</th>
<th>Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>National</td>
</tr>
<tr>
<td>Geographical Area</td>
<td></td>
</tr>
<tr>
<td>Severity</td>
<td>Moderate</td>
</tr>
<tr>
<td>Public</td>
<td></td>
</tr>
<tr>
<td>Economic</td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td></td>
</tr>
<tr>
<td>Interdependency</td>
<td></td>
</tr>
<tr>
<td>Political Effects</td>
<td></td>
</tr>
<tr>
<td>Psychological Effects</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Week</td>
</tr>
<tr>
<td>loss of element</td>
<td></td>
</tr>
</tbody>
</table>

The infrastructure component impacts which fall into this category are limited to periods of recovery of up to a week and impact an entire country. The economic impacts extend beyond the target itself and damage local industries, may cause substantial losses due to reduced energy and require alternative energy sources to compensate some of the missing energy. The remaining criteria must be estimated and requires subjective judgement, in reference to the worst case scenario. As these are not all quantifiable criteria, there are no strict guidelines that determine if they effects are medium or high.
4.4 High

<table>
<thead>
<tr>
<th>Impact Assessment</th>
<th>Degree</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>International</td>
<td></td>
</tr>
<tr>
<td>Geographical Area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severity</td>
<td>Major</td>
<td></td>
</tr>
<tr>
<td>Public</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interdependency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Political Effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychological Effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>&gt; Week</td>
<td></td>
</tr>
<tr>
<td>loss of element</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In order for an infrastructure component to be classed as being critical, several countries must be affected, requiring impacts beyond national boarders and outage times of over a week. The economic effects would be extensive and the cascading effects would possibly cause outages to other services. National measures may not suffice to rectify the problems and political intervention in crisis management may be required. Psychologically the impacts are as such, that they can cause a significant impact on the image of the product/commodity itself. This was the case for nuclear power, the image of which was severely dented through the Chernobyl incident.
5 SCENARIO SIMULATIONS

The simulations carried out for the purpose of this project are theoretical and therefore no guarantee can be given for 100% accuracy. The simulations are carried out on the basis of information available to the consultants and no guarantee can be given for being complete. The scenarios have been designed based on certain assumptions, and depending on subjective opinion of the reader, there is room for opinion differences. It should be noted, that the focus is not the detailing of the scenarios themselves, but an estimate on the impacts they have on various different areas, therefore determining the outage times and the measures in place for recovery of the component/service.

The information on the infrastructure components for the following scenarios has been gathered from data publicly available. Even though it was attempted, the operators could not divulge any further information as this is highly classified. This will be the basis on which an attack can be simulated and the impacts of such an attack analysed. These results will be used to evaluate the strategic importance of the facility with respect to the EU criteria (see 0) to establish the degree of criticality of the infrastructure component. The core focus will remain on identifying the recovery times for the scenarios. Measures and policy recommendations will be formulated for the reduction of outage times after such an attack.

Details of the scenarios are not published but are available to the COUNTERACT Consortium.

5.1 Electricity

The scenario analyzed is an attack on a nuclear power plant with consequences limited to loss of power production. A factor influencing the recovery time of such a plant is the country's dependency rate on the component. The diagram below (Illustration 22 - EU Member State Dependency Rates on Nuclear Power [27]) pictures statistics for some EU countries in 2005. This compares the production of electricity from nuclear power plants and the total amount of electricity consumed, which leads to a possible conclusion about the dependency rates. It is therefore concluded, that the outage of a nuclear power plant has different margins of impacts on the consuming countries.

In the case of say France, the outage of a single plant will not necessarily cause extreme deficiencies, as there are numerous other power plants to compensate for the outage. Should the “image” of nuclear power be further damaged, then for a country with a high dependency rate, EU-wide oppositions to nuclear power may be more problematic.
In conclusion, based on the overall evaluation for the chosen scenario, the power plant is not a critical infrastructure. Except for psychological impacts and the outage times, the overall significance of the power plant in a system context is relatively low. The missing power can be compensated for instantaneously and due to the way the system is set up, no customers should suffer an energy outage. Economic impacts are limited, as are the environmental, interdependent and political impacts.

The recovery time can range between 3 weeks to several months up to a year. The impacts in the short term are not significant, although as time progresses the economic impacts could gradually increase. For this reason it is likely, that the most urgent repairs will be carried out and if there are no radioactive leaks, then the reactor could be restarted.

The scenario shows, that the energy system is resilient to such an incident. Nuclear power plants are built to conceal the radioactive material within and have numerous security measures to ensure safe operation. In some countries, regulations to ensure safety against certain airplane crashes have also been implemented, although these are most likely to be outdated by now. This means, that in most cases, there are other measures that will have to suffice in ensuring safety against such scenarios as has been portrayed in this report.

In talks with the IAEA, the scenario involving this infrastructure component has been determined as non-critical. In comparison to the worst case scenario involving reactors, this scenario overall has shown, that if an airplane crashes into an nuclear power plant, the outage times may be long, but on the other hand, these do not result because of the time needed to recover the component, but due to the safety checks which are necessary. This scenario focused on a more recently built nuclear power plant and thus the same cannot apply for older generation models.

Electricity on the other hand is recovered immediately. The numerous variants (see Illustration 23 - Impact of PWR outage on Electricity Generation) for electricity production reduce the impacts and...
are characteristic in this particular part of the energy system which serves greatly contributes in reducing the total impacts.

Overall, the damage is limited to the generation facility itself and to “atomic energy”, but no consumers are affected by a supply shortage. The outage duration is therefore not the key factor determining the impacts, which is a key issue to be considered in formulating policies at a later stage in this report.

### 5.2 Gas

**Scenario 2:**

Scenario 2 focuses on a LNG Tanker which is hijacked on open waters and detonated causing the entire boat, crew and the shipment to be lost (the method used to destroy the LNG tanker was deemed irrelevant in the analysis of the scenario impacts).

In conclusion, the impacts, which result from this scenario as part of the gas system, are minimal. The entire gas system can easily compensate for the LNG delivery, which was lost, and over a prolonged period of time, this is also sustainable, if the region has numerous suppliers, has the opportunity of redistributing available resources and increasing imports from alternative sources. This is a great advantage of the strategy implemented by Spain.

The recovery time of the LNG is minimal and no customers will suffer a supply shortage. The LNG tanker building times cannot be reduced significantly and in this case is also not essential. The central issue that needs to be addressed in this scenario is to limit the psychological impact.
**Scenario 3:**

An LNG tanker has just departed from the docking facility after unloading the LNG into the storage tanks. With the storage tanks full, the LNG will now be processed in the re-gasification unit. A small vessel equipped with explosives, breeches the security perimeter and rams one of the storage facilities. The consequence is that one of the two tankers is penetrated and LNG spills into the ocean. A spark ignites the LNG resulting in a fireball over the water.

**Summary:**

The two scenarios have - for the same commodity, LNG - shown very different results. In both cases, the recovery time of the LNG lost in each incident is insignificant. The physical characteristics of gas permit it to be stored and therefore allow strategic reserves to be allocated and use to compensate in crisis situations. This is a main contributor to reducing the impact on the public and therefore the economic damage, which is sustained.

The recovery of the infrastructure components, the tanker and the terminal respectively, currently is estimated to take approximately 3 years. There are no feasible measures that can be implemented to reduce these times. The current market situation and technological standard, does not permit reduced recovery times and therefore alternatives must be found.

It was also found, that the most severe impacts were not due to the duration of the outage. Indeed, the duration will possibly cause the impacts to intensify but on the other hand, over a period of three years, the system will adapt to the circumstances, which in turn lessens the extent of the impact. The most severe impact is a cross cutting issue, which is the psychological reaction of the public, coupled with the political reaction, potentially causing an economical disaster.

If planned projects would be put on hold, the consequences in the long-term would far exceed the initial economic impact of the incident itself. The experience with LNG is extensive and safety measures have addressed technical reliability. Terrorism is a new issue, which needs to be addressed, but the threat of an incident can never be reduced to 0%. Measures should therefore not only address individual infrastructure components, but also look for a system wide solution possibly addressing multiple problematic issues.

Certain characteristics of the entire gas supply system can help to reduce the true impacts: Different delivery methods and even distribution of imports from various sources allow for diversification and adaptations to be made in order to respond to the situation. Reserve capacities in the transportation pipelines are another factor that add to the flexibility of a system. This is certainly not the case in all countries throughout the European Union, which could lead to severe supply outages.

The assumed presence of such characteristics have been the main reason, why the impact of scenario 3 has only been moderate. The lack of supply to customers would have radically worsened the overall impacts.
5.3 Oil

The first three scenarios have looked at a generation facility and two transport infrastructure components. In the final scenario, a processing facility for oil has been chosen, demonstrating the dependencies on a single critical infrastructure component. The infrastructure component is assumed to be located within Europe and to be the only one in the region, unlike was the case for the power plant and the LNG terminal and tanker.

Summary:

The scenario has shown the range of impacts that a refinery outage can have. In this example, the outage times are not the main determinant of the impacts as long as the security oil reserves are available. The recovery times therefore are relevant in limiting the damage, but only after a certain amount of time. Before the depletion of the reserves, the impacts are a result of dependencies and uncertainties and not because of the outage duration/recovery times.

Irrespective of the length of the outage, there are numerous processes immediately engaged. These are precautionary measures initiated to control the distribution of reserves and their availability. The type of reserves which are kept play a major role in this scenario. Because only half of the reserves are final products, the 90 day minimum oil reserves are instantly halved, as the other reserves cannot be processed. Alternatives are therefore required.

The initial reactions by markets, politicians, the public and other industry sectors will not be based on the duration of the outage. The incident itself will cause panic and speculation. For this reason, focusing the attention purely on recovery times is not effective alone, but nevertheless is factor which will determine the reactionary steps taken to manage the crisis. The wide spread impacts resulting from this incident will not be reduced by improving only recovery times. Further measures and processes are required to better manage the crisis.

5.4 Scenario Analysis Conclusions and Overview

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Commodity</th>
<th>Infrastructure Component</th>
<th>Level of Criticality</th>
<th>Recovery times of Infrastructure</th>
<th>Recovery times of Lost Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Electricity</td>
<td>Nuclear Reactor</td>
<td>Low</td>
<td>3 weeks - 6 Months</td>
<td>Immediate</td>
</tr>
<tr>
<td>2</td>
<td>Gas</td>
<td>LNG Tanker</td>
<td>Low</td>
<td>3 years +</td>
<td>Immediate</td>
</tr>
<tr>
<td>3</td>
<td>Gas</td>
<td>LNG Terminal</td>
<td>Moderate</td>
<td>3 years +</td>
<td>Immediate</td>
</tr>
<tr>
<td>4</td>
<td>Oil</td>
<td>Refinery</td>
<td>High</td>
<td>3 - 4 Months</td>
<td>Immediate</td>
</tr>
</tbody>
</table>
In the above table, a summary of the final outcomes has been presented. The findings have shown that the outage times do not always determine the initial impacts of the infrastructure component. A system view adopted for the purpose of this study, revealed that it is important to differentiate between the recovery time of the infrastructure component and the recovery time of the energy. This is vital, because it determines where the focus of counter measures must be. If the lost energy, oil, gas or electricity, cannot be recovered and delivered to the end user, then this needs to be the core focus. If this is the case, as was in the previous scenarios, then the next focus must be to keep this supply upright and only when this is ensured, then should the reduction of the recovery times of the infrastructure be addressed. If the prerequisites are met, then the recovery times will most likely automatically be reduced, because the efforts can then be concentrated on replacing the component rather than managing the crisis.

In the various scenarios, which have been evaluated according to the criteria used by the EU to identify critical infrastructure, in most cases the recovery of the energy which was lost due to the attack was immediate. In contrast, the recovery times of the infrastructure components are so extensive, that in most cases, direct measures for reduction of their recovery times are infeasible. Extensive analysis of the scenarios from various perspectives made it possible to find out what measures, formulated as policies, can be implemented to reduce recovery times, but to equally address other concerns of the energy industry.

The likelihood of an incident occurring is a critical factor in risk analyses. The likelihood of a single LNG terminal in Europe being attacked is relatively small. But if other possible incidents are additionally considered, such as workforce strikes, outages due to the weather, technical failures or supply shortages due to political conflicts for example, then implementing a measure which addresses these and terrorist attacks becomes feasible.

The EU criteria for identifying critical infrastructure, although currently not adapted for the specific application within the energy sector, has enabled for comparable measurements of scenario impacts to be made. If the severity or criticality of a scenario would have purely been based on the recovery times, the true extent of the infrastructure component's impact would not have been revealed. The study has highlighted, that the recovery time is a factor, which amongst others, determines the extent of impacts but is not a measurement of criticality on its own.

The scenarios which have been analyzed, demonstrate that the extent of the impacts can be influenced by the time required to recover the energy infrastructure component and therefore defines the role of recovery times in the event of a terrorist attack. The initial impacts though are determined by other issues, which in turn establish the priorities and the order in which crisis management measures are carried out.

So, when trying to prioritize the issues which need to be address by stakeholders so as to improve the reaction to a terrorist attack, reducing the recovery times will not be the foremost priority. The stakeholders' acceptance of policies imposed on them and the willingness to invest, will therefore depend on the issues' priority addressed there within. For this reason, the policy recommendations will address the priority issues which bring mutual benefits, essentially helping improve the recovery times of infrastructure components.

The dependency on the “attacked” infrastructure components and the alternatives method available for compensating the lacking output from the missing component are the primary determinants of the severity of the attack. But throughout the four scenarios, the psychological impacts have consistently been a major concern. It should be noted, that even though the outage times also were consistently high, this is due to the limitations of the criteria. If these were adapted to the
energy sector, they would vary greatly throughout the 4 scenarios, ranging from 3 months to 3 years or more.

In the first scenario involving a nuclear reactor, the long outage time is due to the thorough checks required to ensure that there are no radioactive leakages and that all system components are fully functional for when the reactor is restarted. An outage time of 3-6 months will cease the electricity generation of the affected units, but the reserves and extensive alternative electricity production units compensate for the lacking generation capacity. The physical damage is repaired within a relative short time, the reduction of which will not significantly reduce the overall recovery time of the reactor. The checks are essential and therefore should only be reduced as long as the quality of the checks is not affected.

In the second scenario involving an LNG tanker, the impacts again are not significant from a system wide perspective. Although the tanker could only be replaced after at least 3 years, due to the extensive building and waiting times, the LNG can be replaced within a week’s time, without having to use reserve supplies. With the usage of reserves, the replacement of the lost LNG would be instantaneous, reducing the impacts to an almost purely financial matter. The reduction of the recovery times for LNG tankers is currently not possible. The boom of the LNG market worldwide requires building capacities to operate at their maximum. Spare or replacement tankers will only become available, as the demand surge relaxes and orders for new LNG tankers gradually subside. Temporarily, LNG tankers can be chartered to alleviate some of the damage.

The third scenario which focused on the loss of an LNG receiving terminal, revealed similar results as the previous scenario involving an LNG tanker. Although the extent of the impacts is larger, the recovery times are similar to those of the LNG Tanker. The producers of components for the terminals are struggling to meet the demand. Taking initiatives to reduce the recovery times of the component are again not feasible; although alternatives are required to compensate the gas supply should the outage last over a prolonged period of time.

In the final scenario, the time required to replace the affected component of the refinery, 3-4 months, is overall the shortest. Yet the impact of the facility outage is presumed to be the most significant. Even though the available end product reserves can compensate the immediate losses, it is not sure what the extent of the final consequences will truly be, due to the numerous interdependencies in the energy system. The system is able to cope with planned outages of up to 4 or six weeks, but the circumstances under which these occur are very different, being planned 1-2 years ahead of time. It is not assumed that the recovery times can be significantly decreased, but alternative supply sources, their distribution and consumption measures must be carefully planned to cope with the extensive outage, especially as refineries in Europe are operating at near maximum capacity.

In summary, the four scenarios have not revealed a great potential for the cost-effective decrease of recovery times. Instead, what has appeared to be more important is identifying key mechanisms that allow the energy systems to compensate the loss of infrastructure components, therefore reducing the impacts caused by these outages. Therefore, proactively planning the response to an infrastructure outage would be the most advantageous and could additionally help increase market competitiveness as well as responsiveness to other outage causes, not only to terrorist attacks.
6 PROPOSED STRATEGIES & POLICY RECOMMENDATIONS

The strategies and policy recommendations are based on the findings of the various scenarios of attacks, coupled with the advice gathered from the interviewees and also general issues which have been raised by third party members throughout the course of this project.

One of the main findings in all of the scenarios, was that the recovery times themselves do not solely determine the extent of impacts, but is actually a factor determining the extent of the impacts. The recommendations therefore focus on addressing a broader scope of issues to simultaneously increase the effectiveness and the acceptance of the proposed measures, but paying close attention to the bettering of recovery times there within.

6.1 Recommendation Overview

An outline of the recommendations is given below which will be elaborated thereafter:

General Recommendations:

- National Crisis Management Process
- European Energy System Management (Harmonization of existing and future standards)
- International cooperation with the Stakeholders

Electricity Specific Recommendations:

- Ensure that measures are and can be implemented
- Maintenance standards and proper training should be mandatory
- Spare parts to be stored at strategic locations

Gas Specific Recommendations:

- Cross-borderer cooperation in terms of reserve management
- EU wide crisis response management strategies
- Enhance responsibilities of the Gas Coordination Group

Oil Specific Recommendations:

- Further specify the handling of reserves to incorporate more end products rather than crude oil
- Enhance responsibilities of Oil Supply Group
- Cooperation on spares management
6.2 General Recommendations

The general recommendations for policies have been formulated to address issues on three different levels. The policies are formulated to impact on a national, EU wide and international basis, implemented by governmental bodies.

6.2.1 National Crisis Management Process

Detailed process planned in advance on a national level should make the largest contribution towards crisis management overall and the reduction of recovery times. One of the key elements, which can serve as a basis for all the other policies provided in this report, is the establishment of a national crisis handling process. This includes several elements, starting from the establishment of a designated crisis management team within each European country which is able to take decisions, has access to all required information and is actively updating and progressing crisis management for their country and most importantly, is independent body. The team is to set up a crisis response plan and is responsible for the execution of the plan and coordination of the necessary parties. A further element is the documentation of all critical infrastructure elements and the continuous update of these documents. Processes are overhauled, infrastructure components are updated, networks are expanded, developments, which need to be followed and integrated into a crisis management plan. The crisis management team needs to be interactive, communicating with all major stakeholders, the implementation of which can only succeed with the assistance of a body such as the European Union. The greatest advantage is that this team can deal with several energy related issues, not only focusing on terrorist attacks in the energy sector, but also coping with other crisis issues such as weather hazards. Many of the required tools have already been initiated on a EU level, such as oil reserve tracking systems, which should be adapted as a central tool used by the national crisis management team.

On the one hand, this will allow some of the current tasks of the EU to be delegated and at the same time, the national groups will strengthen the efforts of the EU bodies, such as the Gas Coordination Group or the Oil Supply Group. The structure would have the advantage of possessing local, country specific knowledge and for this knowledge to flow together to coordinate EU wide cooperative actions. Rather than undermining the competences of the industry and the utilities, the National crisis management group can bind these along with those of the government and all other stakeholders into a dedicated crisis coordination plan.

The recovery times would be greatly aided, as crisis issues are handled by a central group and the operator of the facility can concentrate effectively repairing the damaged/destroyed infrastructure component. The national coordination group can facilitate any assistance required, such as in the sourcing of spare parts required to repair the unit.

This clearly is an element, which needs to be specifically defined on a national level for the energy sector, leading to the resolution of a great many number of parallel issues. Processes that are predefined would allow quick effective response to crisis situation, which according to criticality would enable national or international cooperation to resolve these in accordance with all stakeholders. Most importantly, representatives from all the various energy systems, which are highly interrelated, will be in close vicinity of each other and able to directly assist each other.
6.2.2 European Energy System Management

The second recommendation targets a vital aspect of all future policies, which will be made in the EU energy sector. A **European approach** in all future actions pertaining to the energy system, which are initiated by individual Member States, is required. Not only the liberalization process of the markets, but also the quantities of energy consumed by individual countries and the complex system interdependencies make it essential for international cooperation to be a core element of any future project, policy or standard. Decisions’ impacts are not confined to a single system or region, therefore causing undesired side-affects if they are not thoroughly planned. Barriers for the lack of cross-boarder cooperation must therefore be identified, analysed and overcome, to ensure that future actions are mutually beneficial to all stakeholders involved.

More specifically, the benefit for recovery times will come from improved organization of counter measures, which are implemented to respond to a crisis situation. These can be carried out more effectively, which will allow the responsible party to concentrate solely on the problem at hand, possibly with help from neighbouring EU Member States.

Based on the fourth scenario for example, OMV would not have to worry about the re-distribution of resources, as the refineries in Bratislava and those located in Germany would automatically concentrate their exports to compensate the loss of the refinery in Austria; Italy would increasingly supply final products out of their own reserves, which would be gradually replaced when the refinery in Schwechat is operational again. Transportation problems would have also been addressed before hand. In addition, the replacement of the damaged distillation unit could be achieved by the supply of available components from surrounding refineries, which would reduce the waiting time for parts from manufacturers and also reduce the costs for storage of spare parts.

The main benefit resulting from this practise would lie within the reduction of the recovery time, reduction of the economic impacts and the reduction in the storage of spare/maintenance parts. Overall this would be an effective step to reducing the extent of impacts of a terrorist attack, but also be beneficial in the daily operation of refineries.

The further element, which a European cooperation process will gradually need to integrate, is the harmonization of existing and future standards. Each energy system has its own characteristics, which probably also differ amongst the countries, who’s networks though are interconnected. Whether it is future regulations on the integration of decentralised power generation units, the nomination format for commodities or the minimum security standard for gas storage facilities, currently these are all independently progressing within the member state countries. The challenge lies in adapting the historical and the existing requirements and preparing the current system for future requirements. This would imply that the developments would have to be predetermined or that a high degree of flexibility is required, both of which would seem to be infeasible in the short-term. A possible start therefore, is the establishment of harmonized processes. This can be applied to security standards of individual facilities, to the implementation of new technological solutions or to the formulation of future market structures. The basic aim is to identify a single approach in dealing with various issues, which takes the entire system into consideration rather than just a single component.
Based on the first scenario and the findings of electricity market overview, the picture that has emerged across the EU, is that there is no single set of minimum standards throughout the EU making a comparison of the reactor standards very difficult. The IAEA has already published self-assessment guidelines [77] for determining the robustness towards a malicious attack that may have potential radiological consequences and there are several other such process guidelines concerning other relevant issues already available. If these were made compulsory, then a comparative benchmark for such issues could be carried out which would have several benefits. Firstly, operators would see where the weakest parts of their systems are and where improvements are required. Secondly, the infrastructure owner could compare the facility standard to those of the EU and identify where improvements are required, possibly to reach a minimum standard. Thirdly, in terms of security, this would also allow for international cooperative measures to in the EU to be moulded according to these weaknesses. In some cases, such as for the nuclear power plants Golfech 1 & 2, it may be undesirable to increase the security measures aimed at reducing the damage caused by an airplane crash, because ultimately the duration of the outage is due to the seismic checks required to ensure a safe start up of the facility, not structural repair times. In such instances, reducing the recovery times is not advantageous, because the consequences of negligent checks could be worse than the initial incident. Therefore it is possible that EdF aims to further improve their checks.

Similar processes can be established jointly with expert organizations such as the IAEA, who can offer insight and experience in their field of expertise to suit all stakeholder requirements. Gradually, this process will establish a common basis on which standards can be developed and implemented.

Specific for the improvement of recovery times, these processes would enable for better inter-system compatibility, reduction of system vulnerabilities and improve responsiveness to crisis situations.

6.2.3 International cooperation with the Stakeholders

The report has shown that the energy systems extends beyond EU borders and because of this, so do the vulnerable points where attacks can be carried out to harm economies of the European Union. The countries from where the energy sources destined for the EU originate from have realised that their systems are at risk and the security measures in place are insufficient. An attack would not only harm their own energy supplies, but also disrupt the economies, which are heavily reliant on the revenues from the energy exports to Europe. Therefore, this policy recommendation extends the cooperative element from the first two scenarios to outside the EU. There is openness expressed by the source-countries to cooperate with the EU, which would result in a mutually beneficial situation. On the one hand, the overall risks are reduced by the strengthening of some of the fragile points of the entire energy system, which also creates new business opportunities for Europe. At the same time the source-countries would benefit from the experience of the EU.

The increased need for security measures outside the EU can be demonstrated using the situation illustrated in the second scenario. Although there are patrols of certain tanker routes, there are some that are lacking patrols and are prone to piracy. If tried and tested mechanisms or processes
can be introduced, which would ensure better control of the area using the limited resources available to the responsible countries, for example through technological enhancements, then the overall security of the system can be improved.

Policies should therefore aim to increase cooperation with the countries located outside the EU interested in improving their energy system security measures. Policies can address research programs, networking platforms or planning initiatives for new projects, to incorporate those lacking knowledge or technologies.

Essentially, the policies do not only focus on solely reducing recovery times, but they will achieve this as a side effect. This is important so that those implementing the measures and especially those making the investments, are portrayed all the benefits.

These initiatives would be equally beneficial to increasing maintenance and technology standards, therefore tackling the other potential causes for supply outages. Further, these three measures will also address two of the issues, which were found to be the greatest impacts. The economic issue is addressed, through better control and improved reaction to the situation; the crisis can be better managed. This limits the potential economic impact and provides the public as well as the industry with security. If clear steps can be outlined on how the situation is handled, then people will know what is going to happen next, rather than panic due to uncertainties.

These three recommendations can be implemented as policies by the European Union and create a framework that will allow improved crisis management and therefore reduce the amount of time which is required for the reinstatement of energy services after suffering a terrorist attack.

### 6.3 Recommendations for Electricity Sector

UCTE has introduced the “N-1” criteria to enhance system stability. This would ensure that the electricity system is operable even if a single component fails. As the report illustrates, there are countries within the EU who are not able to comply with this criteria therefore representing an increased risk for the entire electricity system. The recommendation therefore would be to ensure that such measures can be implemented by Member States and if they are not, the cause needs to be identified and steps taken to rectify this. If coordinated measures for recovery times cannot be implemented, then the measures will be ineffective. The barriers for implementing the prerequisites for such measures must be eliminated in all Member States.

The report has also highlighted, that system outages in some countries are higher due to technical and operational failures. Maintenance standards and proper training should be mandatory and where they are lacking, measures are needed to ensure this is made possible. Maintenance and therefore also the storage of spare parts is an important issue which was addressed. Cooperative strategies need to be developed, permitting spare parts to be stored at strategic locations for shared usage between several companies. The costs of spare part storages would be shared and the turnaround of these parts increased, therefore avoiding conflicts with warranties. If there are several parties involved, increased spare parts will be stored as the chance of these parts being used is higher. Alternatively, the delivery of spares directly from the manufacturer must be guaranteed, which is a great burden for the manufacturers themselves.

The electricity specific recommendations resulting from the study do not require that extensive measures be implemented specifically to reduce recovery times. It has been found, that increasing
the overall system stabilities would be of greater overall benefit and would reduce cascading effects, therefore reducing the impacts of an outage and therefore the number of components, which are affected.

6.4 Recommendations for Gas Sector

The scenarios concentrating on natural gas have shown that there are several major issues, which need to be addressed, specific to the gas sector.

One of the initial concerns for increasing the response capabilities to crisis situations is the lacking cooperation in terms of reserve management and response strategies. Although the focus is not on recovery times specifically, decreased recovery times will be one of the final benefits resulting from these measures. The interaction between EU Member States is based on informal agreements between companies to help each other, which are not binding by law and thus are not a definite guarantee. Cooperative agreements between countries should help to strengthen supply shortages, therefore reducing the economic impacts and reducing the pressure on the operator. Negotiate of supplies would not be necessary and the operator can focus on repairing the component. The existing agreements, again informal, between operators to help each other, for example with supplying spares, is again a positive aspect, but should binding by law. This enables risk assessments and legislative bodies to incorporate this into a system wide analysis, acknowledging this and recommending this even as a best practice model for those who have not yet implemented such cooperative models.

The similar model that has been developed for the oil sector, guaranteeing minimum oil supplies, is also desirable for the gas sector. The difficulty herewith is that the storage capacities available in individual EU Member States are limited as are the capacities for distribution of reserves to end users. Increasing the amount of gas emergency stocks within a country, not only enhances the security of supply should there be an unexpected outage, but it further acts as a mechanism for the mitigation of price volatility [34]. Both these issues need in-depth analysis but would be beneficial to increase supply security for long term outages, especially due to the increasingly important role that gas will have in the overall energy supply structure. The first step would be to develop a common and cooperative approach on how to respond in crisis situations. The set-up of the Gas Coordination Group is a first step, which will help improve the crisis coordination on a EU wide scale. Enhancing the responsibilities and integrating this group into the process managing the reserves throughout the EU, will bridge the gap until a European consensus on this subject has been achieved. Recovery times would automatically be improved and more importantly, these recovery times would also be guaranteed over a prolonged period of time, if they are part of a management process for crisis situations.

6.5 Recommendations for Oil Sector

The central processing facilities for oil will not be replaced anytime soon. This is not financially, technically nor is it logistically possible. The 90-day reserve policy currently in place needs to be critically reviewed, specifying exactly what types of products need to be available.

A 90-day oil reserve is of limited in the event that a refinery becomes inoperable. The EU reserve requirements do not differentiate between the various product process stages, which is critical if there is no processing facility available. Therefore, a clear differentiation must be made between
the various product stages and possibly adjusting the current regulation, to focus more on the storage of final products, rather than just oil products.

As is the case with gas, the Oil Supply Group established by the EU, needs to have its tasks extended and detailed. Crisis management should be a legally bound process throughout the EU. This ensures that at the time of a crisis or supply shortage, the cooperation of EU companies is guaranteed and overseen by a central unit such as the Oil Supply Group.

Again, the handling of spare parts is an issue, which needs to be addressed. Even though the exact listing of spares was not revealed for security reasons, it has become clear that spare parts storage is expensive and can lead to warranty problems. Cost sharing and cooperation between several refinery operators can increase the spare part availability. This will only be of limited additional value to the maintenance works, as these are planned up to two years ahead of time, allowing plenty of time for the delivery on required parts, unless there is an unplanned outage.

Essentially, the suggested measures for the reduction of recovery times in the oil sector focus on reserve and spares management. This is vital to guarantee that repairs works can commence quickly and at the same time, final product stocks can be distributed to minimize the impact even in the case of refinery outages. The recovery times of the lost energy has been positive throughout all the scenarios, but this is not necessarily the case as energy consumption increases and infrastructure deteriorates.
7 CONCLUSIONS

This analysis has been conducted to analyse recovery times, that is to estimate the time required to re-establish the energy supply service of an energy infrastructure component after it has suffered a targeted attack. Through the simulation of various scenarios, recommendations for measures and policies have been formulated, which reduce the times required for the reinstatement of the energy infrastructure component.

The aim of reducing the recovery times after an attack is to minimize the economical, social and ecological impacts. It was therefore necessary to identify the role of recovery times in such an attack. The simulations have shown that the recovery times are a factor which partially determines the extent of impacts, there is a clear need for differentiating between recovery times of the infrastructure component and recovery times of the energy lost.

The initial approach proposed for this study, to simulate attacks of differing impact degree, low, medium and high, for different energy carriers, oil, gas and electricity, has been enhanced due to the high complexity of the energy system. Three different attack scenarios have been chosen, whose impacts were evaluated and categorized according to a scheme provided by the European Union on identifying critical infrastructure. Upon application, suggestions for enhancements have been provided, to specifically suit the characteristics of the energy system, to assist the European Commission in the formulation of the energy specific criteria. The consultants estimated scenario impacts based on the research conducted, interviews held with industry representatives and feedback from several presentations.

All scenarios have shown that the energy lost through the attack can be instantly replaced. The impact of the attack nonetheless concentrates on economical and psychological impacts, which are initially not influenced by the overall time of the outage. Only when the energy cannot be supplied any longer, do recovery times become essential. Some of the attacks, which have been investigated, result in damage to such a high degree, that pro-active measures precede the importance re-active measures to the attack.

What has been derived from the analysis, is that energy systems are built to withstand natural hazards, the measures for which are in most cases also sufficient to cope with minor attacks, such as those targeted at electricity lines or individual pipelines. The impacts would be negligible and the costs of the measures to improve recovery times of minor incidents would no justify the effect. On the other hand, Europe’s major energy infrastructure components, such as refineries or terminals, are extremely vulnerable and recovery times can only be improved, by promoting the cooperation between EU Member States and through the implementation of a energy crisis management processes.

The electricity system is the only one of the three systems, which have been analysed in this study, which formally applies the advantages of cross border cooperation. Contrary to this, the security measures of the member states in the natural gas and oil sector are based on independent measures and cooperation is not mandatory, but in some cases agreed upon on an informal basis.
Reserve capacities for energy vary throughout Member States, as do dependencies on the energy as well as the standards. This increasing of the complexity of cooperation, although in some instances, the differences may reveal themselves as being the benefits.

The recommendations have thus been structured to address issues in a proactive manner on different levels. Policies should address international cooperation when formulating contingency plans to reduce the impacts of outages and their duration. These need to be based on national contingency plans overseen by a national crisis coordination group. In turn this requires basic process to be implemented across the EU, which will gradually allow standards to be harmonization. Such process guidelines are being developed, for example by specialist organizations, with which cooperation should be intensified, to progress more swiftly in these areas.

Furthermore, it is not feasible to concentrate on the security features of individual infrastructure components. Although there is a need for a basic security level, a system wide view has shown that measures to improve the overall systems resilience against attacks should also take into consideration other beneficiaries of these measures. This is to say, that if the measures implemented will be effective against market fluctuations, multi-component failures, terrorist attacks and against extreme natural hazards, then the investors will be more easily persuaded to engage in these actions. These can then be integrated into long term planning mechanisms of the energy system, allowing proactive measures, rather than reactive measures to implemented, permitting the reduction recovery times.

With respect to planning and cooperation, a concentrated effort should be made to incorporate the countries from which our energy sourced. As the report has shown, a large part of the energy is imported from various countries, whose standards and security measures may not be at the same level as that of the EU. There is a large discrepancy in this area, but also a sign of willingness from those countries to improve their systems. Therefore, the EU should establish an information exchange network with these countries to transfer knowledge and technologies. This would simultaneously also offer a chance for new business models to develop.

International terrorists have noted the fragility of the energy system. Attacks have affected central targets within Europe, but the impacts of future attacks can be drastically reduced should Europe decide to a.) Nationally manage energy crisis situations, b.) Take a European Approach to energy related matters and c.) Cooperate with those countries supplying resources to the EU. These methods are efficient and cost effective and benefit various areas, reducing recovery times and improving response to energy crisis situations. This will aid Europe in ensuring secure and long- and short-term energy supply in a rapidly developing environment, but maintaining the current standard of living.
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