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Environmental Impact Assessments for Completion of Rivne Unit 4 and Khmelnitsky Unit 2 Nuclear Power Stations. Addendum. Environmental Impact of the Non-Nuclear Alternative

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1.0 INTRODUCTION

In December 1995 the Governments of the G-7 countries and the Commission of the European Communities signed a Memorandum of Understanding (MOU) with the Government of Ukraine concerning the closure of the Chornobyl nuclear power plant. Section 2 of the MOU states that the Ukraine and the G-7 will work with international financial institutions as well as foreign and domestic investors to prepare loan-financed projects based upon least-cost planning principles for completion of Khmelnitsky unit 2 (K2) and Rivne unit 4 (R4) nuclear reactors, for thermal and hydro plant rehabilitation and pumped storage projects, and for energy efficiency projects in accordance with Ukraine's energy sector strategy.

An Environmental Impact Assessment (EIA), including a radiological assessment, for completion of K2 and R4 has been prepared and circulated as a basis for consultation with interested parties [1, 2]. The EIA considered the base case alternative to completion of K2 and R4 i.e. continued operation of the Chornobyl NPP, but did not consider the non nuclear least-cost alternative since, at the time of preparation of the EIA, the necessary source term information was not available.

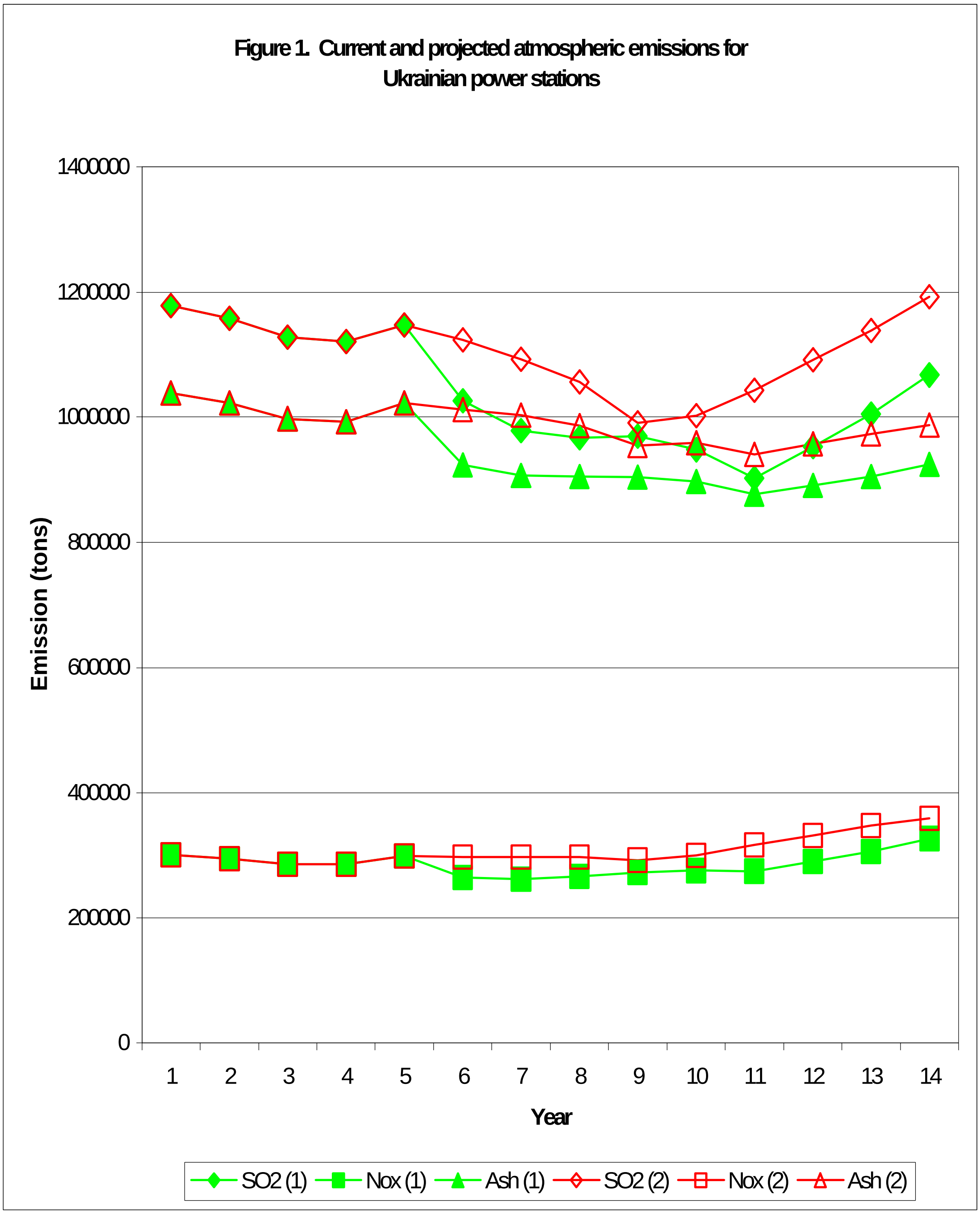
The non nuclear least cost alternative to completion of the K2/R4 nuclear power plants is greater utilisation of existing thermal power plants. A report on the technical and economic issues associated with this alternative has recently been prepared by Stone & Webster. Additionally, the European Commission, through its TACIS programme, has supported a number of relevant studies. In order to satisfy the requirements of its Environmental Policy and Procedures [3], EBRD required a qualitative analysis of the likely environmental impacts of the proposed non-nuclear least-cost alternative to completion of the K2 and R4 nuclear power plants, the terms of reference for which are set out in Appendix A to this report. The power stations included in the present report were selected by EBRD taking into account a range of factors and to provide a representation of the range of diversity of plant, modernisation and local environment.

This report therefore provides a qualitative analysis of the environmental impacts of the non nuclear least-cost alternative. Section 2 provides the baseline source-term for discussion of the environmental impacts of the non nuclear least-cost option. Section 3 provides a description of five of the sites selected for study, based on visits undertaken over the period April – June 1998. Section 4 summarises potential environmental impacts associated with continued operation, greater utilisation, and/or modernisation of the selected plants. Conclusions are set out in Section 5.

2.0 SOURCE TERM

The US Electric Power Research Institute (EPRI) has provided results of model analyses of likely discharges of key atmospheric pollutants as a consequence of electricity generation in Ukraine including or excluding the K2 and R4 nuclear power plants [4]. These results are provided both in terms of total quantity of pollutant generated on an annual basis for the period 1997 to 2010, and as a breakdown for each of the power stations included in the analysis on a year by year basis.

Figure 1 provides an example of the total estimated production of NO_x, SO_2 and ash for the alternative non nuclear option (i.e. K2 and R4 not operating, option 2) and for the basecase in which K2 and R4 are assumed to operate with effect from 2002 (option 1).



Note: Year 1 represents 1997.

An example of data for individual sites and for a single year (1997) is provided in Appendix B.

3.0 SITE DESCRIPTIONS

The following general descriptions of the five power station sites are based on visits undertaken during April-June 1998 and on information provided by the management at each site.

3.1 Starobeshevo

3.1.1 Site context

The Starobeshevo power station is situated in the South East of Ukraine in the Donetsk Region (see Figure 2). The site is established on land surrounded on three sides by the cooling reservoir (Figure 3) and mostly occupied by the associated settlement of Novyi Svet, associated light industry and small holdings (including some areas occupied by fruit production). The land surrounding the other side of the reservoir is largely agricultural.

The power station was constructed in the 1950s. The first phase of construction involved three units each of 100 MW. The first of these units was commissioned in 1958 and the last in 1959. The second and third phases of construction involved ten units each of 200 MW. The first unit of phase two was commissioned in 1961 and the sixth in 1964. The first unit of phase three was commissioned in 1965 and the last in 1967.

Two of the original 100 MW units have been removed and one has been retained for critical situations. The fourth block (i.e. the first of the 200 MW units) is currently being reconstructed (see below). The other nine are operable. However, the 200 MW units have been re-rated as 175 MW due to the inability of the boilers to provide sufficient capacity for the turbines. Very little remains of the original design.

The fuels being used are also very different from the original design. The design was for a calorific value of 6,100 kcal/kg whereas the utilised fuels have a calorific value of less than 5000 kcal/kg and there are periods where the average can fall to as low as 4000 kcal/kg. Consequently, significant quantities of fuel oil are being used (providing up to 40% of the heat production). However, the overall calorific value has been improved in the last year to 4800 kcal/kg allowing a reduction of the fuel oil component to 12% of the heat production. In May 1998 the ash content of fuel was between 36 and 38%.

The site has the potential to utilise up to 100,000 m^3/hr of gas to generate 400 MW.

Only two of the units were operating during the site visit. The reason for this was stated to be the spring flood production of electricity from hydroelectric stations.

The total staff of the power plant is 2800 persons of which approximately 700 are support staff. A large number of personnel are involved in maintenance and reconstruction programmes. The supporting settlement has a population of 10,000 persons. Part of the settlement is owned by the power station but, in due course, will need to be transferred to the municipality.

Figure 2
Location of power stations included in the present study

Figure 3
Map of area around Starabeshevo power station

Figure 4
Starabeshevo power station

3.1.2 Anticipated future developments

As noted above, unit 4 is currently under reconstruction. The current modernisation project involves a loan of 113 million USD provided by EBRD. The loan agreement has been signed, a tender exercise completed, and the second stage of a tender is underway to select a general contractor. Work began in March 1997 and, using local staff and facilities, the boiler has been removed from Unit 4. It is intended that the replacement boiler will allow for more diversity in the fuels utilised by the power station. The low pressure systems in the turbines are considered to be of very low efficiency. Discussions have taken place with various organisations concerning the possible replacement of turbine components. The proposed modifications would result in 10-12 MW additional output per turbine. There is also a longer term intention to replace the heaters and several detailed proposals have been prepared. These modifications are estimated to result in a 1.5 - 2.0% improvement in efficiency. Further improvements in efficiency could be gained by changes to move steam condensation to a later stage in the process but detailed evaluations have yet to be completed. In the longer term it is intended that the power station will utilise slag from nearby mines with a calorific content of 3000 and up to 60% ash content.

3.1.3 Fuel storage

The coal storage area (Figure 4) is designed for 745,000 te but has been used to store up to 1.5 million te. There is no barrier between the stored coal and the underlying soil. There are plans to change the design of the area when the site is able to utilise a wider range of fuels.

Initially the fuel oil storage area consisted of two 2000 te elevated tanks and three reserve tanks with a capacity of 10000 te. Subsequently a further two 2000 te tanks were installed. No major spillages have been recorded from the fuel oil storage area.

3.1.4 Water supply and disposal

The cooling reservoir on the Kalmius River was designed specifically for the power station. It has an area of 9 km^2 and a capacity of 44 million m^3. The site is designed with two water discharge points. One at the upstream end of the reservoir which is used in winter to prevent ice formation, and one at the downstream end which is used in summer to provide for maximum loss of heat out of the reservoir. The flow through the reservoir is between 7 and 8 m^3/s. In addition to the reservoir, the site has three cooling towers with a cooling area of 4000 m^2 each, as a reserve if the cooling reservoir cannot provide sufficient capacity. Prior to 1989 there had been problems with the reservoir overheating but such problems reduced with reduced power production.

There is a fish farm on the reservoir but it is not the property of the power station.

Process waters (with a hardness of 35 mg/l) are taken from the reservoir and any discharges of process waters are directed to the ash storage area.

The reservoir waters are also used for irrigation.

Surface waters from the site can be directed to residual tanks if necessary to allow for subsequent mechanical separation.

3.1.5 Discharges to atmosphere

The site has no electrostatic precipitators. There are wet scrubbers with a stated efficiency of between 92 and 93%. There are five stacks in total. The first served the first phase of the power station and therefore is practically not used at all. The next two intermediate height stacks serve the first two 200 MW units. The next two at 250 m height each serve three of the 200 MW units.

Prevailing winds are Easterly.

The norms on discharge are set by the local Environmental Protection Committee and have been developed taking into account current designs and on the basis of Ukrainian standards. However, in practice, the standards cannot be met and the station, like others, is stated to be working in accordance with temporary norms agreed with the local Environmental Protection Committee and established by a neutral organisation.

It is understood that a large amount of work has been completed on possible replacement of the scrubbers. The stated intention is to meet discharge standards of 200 mg/m^3 SO_2, 200 mg/m^3 NO_x, 250 mg/m^3 CO and 50 mg/m^3 dust.

3.1.6 Ash and slag production and utilisation

Apart from a small quantity of ash used at the ferro-concrete plant, ash is currently not utilised. Several years ago the power plant would have expected to utilise approximately 200,000 te per year out of an annual production of 1 million te per year. Currently there are specific problems with the high carbonate level (up to 18%) in the ash due to the use of anthracite in the fuel. However, after completion of the fourth block (above) an improvement in the quality of ash is expected due to the addition of lime to the fuel.

Ash from the scrubbers is removed as slurry to the ash storage area. This system recycles the water associated with it.

Ash is stored in an ash storage area located approximately 1 km away from the power station and on the other side of the reservoir. The design volume of the storage area is 25 million te and the area contains 30 million te. A new storage area has recently been completed and it is anticipated that this will provide for 30 years of ash production.

3.1.7 Other solid wastes

Production of other solid wastes is stated to be small. Such wastes include wood and metal reclaimed from coal (see Figure 4). Metals are recycled commercially. Other solid waste is directed to a landfill designed for industrial waste (stated to be 40 years old) according to official requirements. Resins from water treatment are returned to the manufacturer.

3.1.8 Energy utilisation

The power station currently utilises between 10-11% of its own energy production.

3.2 Burshtyn

3.2.1 Site context

The Burshtyn power station (Figure 2) is located on the banks of the Gnila Lipa River in the Galich District of the Ivano-Frankivsk Region in Western Ukraine (Figure 5). The area is mostly agricultural with the main areas of production being livestock, sugar beet and potato. Local industry includes small enterprises in the building sector and processing of agricultural products, particularly sugar beet.

Meteorological data for the Ivano-Frankivsk meteorological station are stated to show average values as follows: wind speed - 2.9 m/s; wind direction – 80% NW and 20% SW; temperature 3 ^{o}C.

The plant was constructed over the period 1962 to 1969. There are twelve units each with a power rating of 200 MW. The boilers were designed to start with heavy fuel oil and to burn coal. In 1984, further changes were made to allow for utilisation of natural gas. The power station currently uses a mixture of 80% coal and 20% heavy fuel oil with the major part of the utilised coal coming from the Silesian coal basin in Poland, supplemented as necessary by sources from the Lviv-Volin and Donetsk basins. In 1997, the power station utilised some 3.5 million te of coal and 400,000 te of heavy fuel oil. The ash content of coal being utilised in June 1998 was 35%.

3.2.2 Anticipated future developments

There are a number of plans for modernisation of the Burshtyn power station. First, there is an intention to carry out a life-extension study. Secondly there is a proposal under development to upgrade units 8-12 to the same level as units 1-7, and a tender has been announced for installation of an electrostatic precipitator on unit 8. Additionally, talks are underway concerning full modernisation of units 1-6 using both foreign and locally-produced equipment.

3.2.3 Coal storage

Coal is supplied to the site by railway either via storage or directly. The actual coal stock at the time of the visit (June 1998) was in the order of 250,000 te; the designed storage capacity is 1 million te.

The capacity for storage of heavy fuel oil is 60,000 te.

The capacity for gas supply is 350,000 m^3/hr.

Figure 5
Map of the area around Burshtyn power station

Figure 6
Burshytn power station

3.2.4 *Water supply and disposal*

A cooling reservoir (Figure 8) with a capacity of 50 million m^3 was constructed at the time of construction of the power plant. The reservoir was constructed on the Gnila Lipa river and has an area of 14 km^2. Cooling water is supplied to the power plant by three on-shore pumping stations. Cooling water is returned to the reservoir via two canals, one of approximately 100 m length, and one of approximately 5 km length. The distribution of water between the two canals depends on the temperature of water in the cooling reservoir. The maximum temperature allowable in the cooling reservoir is 32 ^oC.

Process waters are subject to a phosphate-hydrazine treatment due to the nature of the construction of much of the equipment. Process waters are discharged to the ash disposal system after neutralisation. Waters from the ash transport system are recycled.

There is currently no treatment of water abstracted from the reservoir to reduce biological activity.

The reservoir is used for fish farming but the fish farm is under the control of the Regional authorities.

Water quality in the reservoir is monitored on a monthly basis by the local Industrial-Sanitary Laboratory and the control points include the city beach and the discharge canals. Monitoring does not include heavy metals or any bacteriological parameters due to the lack of appropriate analytical equipment.

3.2.5 *Discharges to atmosphere*

The average sulphur content of coal utilised at the power station is reported to have fallen from approximately 4.5% to between 1.2 and 2%. This reflects increased use of coal from the Silesian basin.

There is a package of authorised norms for discharges to atmosphere. This was elaborated by 'UkrPTILesproject' in conjunction with the Regional Sanitary and Epidemiological Station and the Burshtyn City Council, prior to approval by the Regional Department of Environmental Safety. For 1998, the following annual discharge limits were imposed:

Dust	39,607 te
SO_2	120,220 te
NO_x	15,925 te
V_2O_5	5,036 te

These limits apply prior to application of any control systems. Electrostatic precipitators are used on units 1 to 7 and are stated to have reduced dust concentrations in the discharge from 1 g/m^3 to between 400 and 450 mg/m^3. Precipitators have not been installed at the other units due to lack of funds. The efficiency of the precipitators is checked once a year by measuring the content of ash in the inlet and outlet.

The Industrial-Sanitary Laboratory determines the concentration of pollutants in ground surface air at distances of 2.5 to 8 km from the site. An example of such data was provided as follows.

Substance	Max. allowable concentration (μg/m^3)	Measured concentration (μg/m^3)
Particles	0.3	0.25
SO_2	0.5	0.24
NO_x	0.085	0.037

It is not clear to what the above data relate i.e. in terms of distance from the site, averaging period etc.

Gross discharges of pollutants have been reported as shown in Table 1.

Table 1
Gross discharges of pollutants from the Burshtyn site

Year	Substance (x 1000 tons)		
	Dust	**NO_x**	**SO_2**
1975	136	32	427
1980	123	28	442
1985	68	26	264
1990	59	27	222
1995	58	20	134
1996	40	14	87

3.2.6 Ash and slag production and utilisation

In 1997 the power station produced 822,000 te of ash-slag waste including 627,000 te of ash and 155,000 te of slag. Ash and slag are transported via a slurry system (though some slag may also be transported by lorry). The nearest ash disposal and slag storage areas (Figure 6) are located on the shores of the cooling reservoir approximately 1 km distant from the power station administration building. The slag storage area includes a construction material enterprise which produces slag gravel for use in concrete production. This facility is able to process 80,000 te of slag per year – the rest is used by other enterprises in the district. The slag storage area was filled to 95% of its capacity and some sections had been partially rehabilitated.

Ash from the electrostatic precipitators is removed as slurry to one of two disposal areas. The first is close to the power station site (alongside the slag storage area, above). The second is located approximately 5 km from the power station. Approximately 15,000 te/yr of dry ash (the lightest fraction) is sold. The designed capacity of the ash storage areas is 20 million te and the areas were stated to be full. A feasibility study was in hand to identify additional areas of land that could be used for ash disposal.

There is no constant environmental monitoring of the ash disposal sites. It was reported that the subject had been studied by scientific institutions and that the most recent research, in 1997, had concluded that any impacts were insignificant.

3.2.7 Other

The power station makes payments for its use of natural resources, discharges and waste disposal. These payments are, for power supply enterprises, currently on a reduced tariff (10% of the full payment) and, for Burshtyn, amounted to 900,000 hrivnas in 1997.

3.3 Kurakhiv

3.3.1 Site context

Like Starobeshevo, Kurakhiv power station is situated in the Donetsk Region in the South East of Ukraine (Figure 2). The power plant is approached through largely agricultural (arable) land and small villages. The terrain is mostly flat (Figure 7).

Construction of the power station started just before the outbreak of the Second World War and the first unit was commissioned on the first day of the war. Equipment was removed from the site during the war and reconstruction started after the war using funds supplied by Germany. This was a pioneer site for the development of high-pressure equipment. The first unit commissioned was 50 MW and the second 100 MW. In the second phase of development, starting in 1971, seven 210 MW units were installed with full commissioning by 1975. Earlier equipment was removed at this stage.

The boilers were designed to work with the lowest quality fuels from Vorkuta and Pechora in Russia, more locally from Kemerovo and Kuzbass (also in Russia) and from Georgia. Previously the power station had access to over 70 sources of fuel but currently it is limited to local supplies supplemented by sources from Poland. The units were designed to work with fuel of calorific value 4100 kcal/kg and are also able to burn slag left from enrichment of coal, coal dust and slag stored at mines. The current calorific value of fuels being utilised is between 2500 kcal/kg and 3500 kcal/kg, the water content is between 12 and 18% (against a design figure of 8.8%) and the current ash content of fuel is between 35 and 38% and even up to 44% (against a design figure of 32-40%).

Only two units were operating at the time of the visit and well below capacity (i.e. in the range 20-100 MW). The furnace temperature was stated to be in the order of 1200 ^{o}C.

Kurakhiv is the only power station within Donbass Energo that does not have any capacity for operating with gas.

The total work force is approximately 2000 persons including all support staff. The nearby settlement which provides the infrastructure for the power station has a population of 25,000.

3.3.2 Anticipated future developments

Plans for modernisation involve developments to burn even lower grade fuel, to improve the efficiency of the electrostatic precipitators, to replace worn out equipment, and to develop options allowing for the use of fuel with a higher gaseous production so as to be able to deal better with mixed fuel sources.

Figure 7
Map of the area around Kurakhiv power station

Figure 8
Kurakhiv and Zmiev power stations

3.3.3 *Fuel storage*

The site has a coal storage facility with a capacity of 1,200 million te. It was designed for 643,000 te but was subsequently modernised and extended. Coal is moved only by front-end loader (no cranes are available). The storage facility has a clay liner established over the natural soil (Figure 8). There are two bunkers (total capacity 400 te) per boiler. Current utilisation of coal at full capacity is 118 te/hr.

Fuel oil storage is provided for by four 3000 m^3 tanks and one 1000 m^3 tank. There has been one major oil spillage due to the failure of a storage tank.

3.3.4 *Water supply and disposal*

Cooling waters are provided from a specifically designed cooling reservoir formed by two dams on the River Vovcha. This provides process waters as well as cooling waters. The volume of the reservoir is 64 million m^3. The reservoir is operated in conjunction with a second reservoir upstream at Kalovsky. In addition to the river and the upstream reservoir, the site is currently allowed to take 8 million m^3 per year from the Siversky Donetsk canal (previously this figure was 12 million m^3/year).

A fish farm is operated on the cooling reservoir but is not the property of the power station. Other fish have been introduced into the reservoir in order to maintain an ecological balance and to control biological problems with inlet water. Previously there had been difficulties with the build up of molluscs in pipe work but this has been overcome by a programme of more frequent cleaning of pipe work. On the other hand, some build up is desirable since it provides a biological system for maintaining high carbonate concentrations in the circulating water.

By calculation, the reservoir has approximately 1 million m^3 of accumulated sediments. A proposal is being considered to remove the accumulated sediment from the old river bed so as to allow the re-establishment of natural springs. This would both increase the capacity of the reservoir and ensure a lower temperature in the circulating waters.

Surface water from the site is directed to the reservoir without treatment. However, if necessary, polluted waters can be passed through a mechanical treatment system before discharge. A separate canal exists for drainage from the fuel storage area. A system for treatment of waters arising from this area has been considered but has not been implemented.

3.3.5 *Discharges to atmosphere*

The units use electrostatic precipitators designed in the 1950s with a stated efficiency of 97%. There is one precipitator with three fields per boiler. There are two stacks each 250 m high, one is connected to three units and one to four units. The other lower stack relates to original development of the site and is not in use. A 2.5-3 km buffer zone has been established between the power station and surrounding settlements.

Prevailing winds are Easterly.

The site wishes to achieve a limit on discharge of dust of 50 mg/m^3 but, at full operation, can achieve only 1.6 g/m^3. No information has been obtained on discharges of SO_2 and NO_x. A series of computer programmes including dispersion models have been developed to calculate the impacts of discharges of different contaminants to atmosphere. These models serve as the basis for limits agreed with the local Environmental Protection Committee. All relevant information on the limits and on their control is available for inspection.

As part of a USAID programme, Donbass Energo has been supplied with an Enerac analyser that is used throughout the company for air quality measurements. This is used on a regular basis according to an agreed plan and additional measurements can be requested by the individual plants. The Environmental Safety Inspectorate has a laboratory which has been equipped with German instruments and which undertakes independent measurements.

Firm proposals have been developed for replacement of the electrostatic precipitators. The related reports also include an assessment of the environmental impacts of the proposals and of the methods required to reach European standards on discharge to atmosphere. There are also relevant reports of work funded by TACIS on modernisation of the plants, one of which is devoted to Kurakhiv and Cherkassy power stations.

3.3.6 Ash and slag production and utilisation

Ash from the precipitators can be removed dry or as a slurry. When removed dry it is used as a supplement in the production of cement and for the production of construction materials. What is not used is transported in the same slurry system as is used for boiler slag. Water from the slurry transport system is re-utilised, either within the ash lagoons or as process waters.

The power station operates two ash disposal systems. One is close to the lower dam of the cooling reservoir about 4 km from the power station. It has an area of 160 ha. This has been overfilled and covered. The second site is under reconstruction. It is 11 km from the power station. It was also almost overfilled so one half has been redesigned using older ash to construct overlapping dams. This is expected to provide for a further four years of operation at maximum station capacity and therefore would allow for similar reconstruction of the other half. A technique has been demonstrated but has not yet been used in practice to utilise polymers applied by helicopter during construction works so as to reduce problems with dust generation. The two disposal systems provide a total capacity of about 60 million m^3 with the recently reconstructed half of the second providing between 24 and 25 million m^3.

3.3.8 Energy utilisation

In current operating conditions, the power station utilises about 14% of its own energy production. This is a significant increase on past operation where a figure between 10 and 11% has been achieved.

3.4 Ladizhin

3.4.1 Site context

Ladizhin power station is situated in the Vinnitsa Region of Ukraine, South West of the capital, Kyiv (Figure 2). The site is approached through largely agricultural land (Figure 9) stated to be high quality arable in nature.

Figure 9
Map of the area around Ladizhin power station

Figure 10
Ladizhin power station

The power station was constructed in 1970 as six units each of 300 MW. All units were designed to run on gas or coal and can use heavy oil as a reserve. Gas has been cut off only quite recently. The units were designed for highly reactive types of fuel with emissions of 40% or more of reactive gases. The boilers operate at very high temperature. At present Polish coal with a 17-18% ash content and a calorific content of 5000 kcal/kg is in use. In contrast, Donetsk coal has a 40% ash content. Coal from Russia, Poland, Donbass and Western Ukraine has been used in the past and may be used again in the future.

The power station employs 900 persons for operational purposes (four shifts of eight hours each). The local settlement has a population of approximately 10,000.

3.4.2 *Anticipated future developments*

Plans for modernisation include refurbishment of the electrostatic precipitators, investment in reconstruction of the ash storage areas (including utilisation of the ash), and staged refurbishment of the boilers and turbines to improve their efficiency. There are plans and proposals to replace transformers (there has been a transformer fire in the past) and to upgrade switch gear etc.

3.4.3 *Fuel storage*

The site has storage for up to 1 million te of coal (Figure 10). All loading is by front-end loader.

3.4.4 *Water supply and disposal*

Cooling water is provided via a specially constructed reservoir (Figure 10) which obtains its water from the Pivdeny Bug by pumping. The reservoir has an area of 20 km^2 and a capacity of 150 million m^3.

Heat generated by the power station is used in fish farming, production of shrimps and production of wildfowl. The plant management has held discussions with a foreign company about the production of Spirolena to produce various algal derivatives. Locally produced Spirolena has been used to demonstrate its qualities for production of such derivatives.

Process waters are treated using demineralisation.

3.4.5 *Discharges to atmosphere*

The power station makes use of electrostatic precipitators with a stated efficiency of 98-99%. The site has two stacks each 250 m high, and each servicing three units.

3.4.6 *Ash and slag production and utilisation*

Previously the power station burnt approximately 6 million te of coal a year resulting in 2 million te of ash. Currently 2.3 million te/yr of coal is burnt resulting in 0.8 million te of ash. The stated split between wastes was 70% to ash and 30% to slag.

Ash and slag are collected and re-utilised. The carbonate content of the slag is very low (due to the high boiler temperature). Dry ash is loaded into wagons for use in the cement and building industries but such utilisation has declined recently because of the high cost of railway transport. It has also been used as an admixture to local clays for brick production. Two plants for utilisation of waste have been constructed but not commissioned.

The nearest location for ash storage is some 10 km from the site (reflecting the quality of the surrounding soils for agricultural purposes). The pumping process requires three lifts from the power station to the disposal lagoons. The storage site is currently full with 25 million te occupying a design capacity of 14 million te. The maximum period for further operation of the storage area was stated to be three years.

3.4.7 Other solid wastes

Other solid wastes include those arising from the demineralisation process. The quantities of such wastes are stated to be very small and the wastes are disposed of to the same area as is the slag.

3.5 Zmiev

3.5.1 Site context

Zmiev power station is situated in the Kharkiv Region of Eastern Ukraine (Figure 2). The power station settlement (Komsomolsky) is approached through an area of undulating countryside that includes wetlands (reed beds) interspersed with natural forest or pine plantations (on the higher ground) and some agricultural activity on the slopes between the forest and the wetland (Figures 8 and 11). The agricultural land is mostly pasture.

The site had a design capacity of 2400 MW provided by six units of 200 MW each and four units of 300 MW each. The first unit (200 MW) was commissioned in December 1960 and the last unit was commissioned in 1969. The first phase (6x200 MW) was designed to work on gas (at that time it was envisaged that local gas reserves would last for up to 100 years). However, even during construction of the first phase, it became clear that changes would need to be introduced to use hard coal as a fuel (calorific value 6000 kcal/kg). During the second phase of construction, the specification for the fuel was further reduced to coal with a calorific value of less than 5000 kcal/kg. Consequently, many changes were introduced to the original design. Thus, although all units could technically run on gas they have been redesigned to work with poor quality coal. The power plant was designed to serve the Kharkiv, Poltava and Sumi regions (in combination with a number of local power plants).

The average calorific value of fuel being burnt at the time of the visit was stated to be 4400 kcal/kg with a 32% content of ash. The fuel was being supplied locally from the Donbass area.

The power station has a staff of approximately 2000 of which 1600 are technical staff. The plant supports approximately 17,000 persons living mostly in Komsomolsky.

Figure 11
Map of the area around Zmiev power station

3.5.2 Anticipated future developments

Within the former Soviet Union there had been a plan for refurbishment of the power station involving both technical aspects (boilers and turbines) and environmental protection (replacement of the precipitators and reduction of emissions of SO_2 and NO_x). Discussions have taken place with various organisations regarding replacement of the boilers allowing for continued utilisation of a range of fuels. The plant is looking to use coal from the Donetsk area as well as from Rostov and the Kuzbass basin (in Russia).

3.5.3 Fuel storage

The design capacity of the coal storage area is 452,000 te. Coal is stored in an open area 500 x 70 m. During full operation of the site the rate of utilisation of coal is in the order of 18,000 te/day.

3.5.4 Water supply and disposal

Cooling waters are provided from a specially constructed reservoir. The area of the reservoir is 12.5 km^2 and the volume is approximately 50 million m^3. Cooling waters are discharged to the reservoir upstream of the inlet. No blow downs to the cooling reservoir are allowed.

An area of 1.2 ha of the reservoir close to the outfall is used for fish farming. The fish farm is run by the local administration.

Process waters are supplied from the Siversky Donets river and are subject to chemical treatment.

Liquid wastes pass through a three stage mechanical separator to remove oil products and are then combined with domestic wastes. Domestic wastes are discharged to the municipal waste treatment works (owned by the power plant) after combination with liquid waste streams from other facilities. The final discharge from the domestic treatment works is to the Siversky Donets river after passing through a series of natural reservoirs. The limits on discharge were stated to be very ‘tough’ and to be well enforced by the local Inspectorate. The power plant has met all restrictions on discharges of liquid wastes but the Siversky Donets does not meet specific criteria for parameters such as ammonia, oil products and sulphates. Monitoring is carried out by the local laboratory with the results provided to the local Sanitary Inspectorate. There have also been some instances of high copper levels but the source has not been determined.

Drinking water is supplied from wells. There are five at approximately 100 m depth providing water at 8-10 ^oC and six at 800-900 m depth providing water at approximately 28 ^oC. The two sources are combined in a single reservoir. The nearest of the wells to the power plant provides drinking water for the plant.

Groundwater has been monitored for the last ten years by the Kharkiv Institute of Ecological Problems using a network of 70 boreholes; the quality of waters is considered to be very high.

3.5.5 Discharges to atmosphere

The 300 MW blocks have electrostatic precipitators whereas the 200 MW blocks have only water scrubbers. The overall efficiency of removal of atmospheric contaminants was stated to be only 90-92% reflecting the fact that the original design of the plant was for utilisation of gas.

Discharges are via five stacks, one at 180 m, two at 120 m and two at 250 m, the different heights reflecting the historical development of the site. The units operating at the time of the visit were the ones that were utilising the taller stacks.

Limits on atmospheric discharges are set by the local branch of the Ministry for Environmental Protection and Nuclear Safety, and are set on a stack-by-stack basis. The original basis for calculation of the limits was from the North East Centre of the Academy of Sciences. Actual discharges were stated to be approximately 60% of the set limits. The limits for emissions were stated to be 100,000 te of 'sulphate' and 80,000 te of NO_x.

3.5.6 Ash and slag production and utilisation

Slag from the boilers is removed as a slurry for subsequent disposal. Ash from the precipitators can be removed either dry (for subsequent utilisation) or wet. Ash from the scrubbers is removed as slurry. Techniques for utilisation of ash have been developed but are used to only a small extent. Ash was used as a substitute material for cement production. Slag was used in road construction and in building materials. The radioactivity content of the slag is low and the plant has a certificate allowing for its use in construction materials. Approximately 150,000 te is utilised per year and sometimes as much as 200,000 te per year.

The ash storage facility has an area of 350 hectares but is currently fully utilised. Its current volume is about 22 million m^3 but is to be increased by increasing the height of the surrounding dams. Water from the slurry transport system is recycled.

4.0 ENVIRONMENTAL IMPACTS

This Section provides a qualitative discussion of the environmental impacts that might be expected to be associated with continued operation of thermal power plants in Ukraine based on the source term information provided in Section 2 and on material obtained during visits to the sites as described in Section 3.

For atmospheric pollutants, a scoping calculation is provided of concentrations likely to occur at a given site. It is not possible to scale any quantitative analysis to 2000 MW to provide a direct comparison with the impacts arising from the proposed K2/R4 completion project since few of the sites concerned, or options that have been considered, allow for this level of power generation at an individual site. The closest comparison with either K2 or R4 in energy generation terms is with Starabeshevo where the analysis described in Section 2 allows for operation of six 200 MW units (total capacity 1200 MW). Since those units are currently downrated to 175 MW each, the total generating capacity is 1050 MW.

4.1 Use of natural resources

All thermal power stations are major users of natural resources whether it be coal, oil or gas. The total quantities of fuel utilised are dependent on factors such as its calorific and ash content and the design and operation of the furnaces used to supply heat to generate steam.

4.2 Supply, storage and handling of fuels

Operation of coal-fired power stations requires the supply, handling and storage of substantial quantities of coal.

Mining and supply of coal result in several environmental impacts, the discussion of which is outside the terms of reference for this study.

With a general move to lower grade coal, handling operations can result in production of substantial quantities of dust during delivery and during subsequent transport to the burners by conveyor. The five power stations considered in the present study are generally sited in relatively open conditions, covering large areas, and associated only with urban conurbations that provide for the supporting settlement. Given this general site context, dust generation is unlikely to result in off-site consequences but does pose a potential hazard for workers.

Several of the sites visited during the present study were storing much greater quantities of coal than was intended by the original designs of the storage areas (e.g. 1.5 million te at Starabeshevo compared with a design capacity of 745,000 te, and 1.2 million te at Kurakov compared with a design capacity of 643,000 te). This is presumed to reflect the fact that, in general, the power stations are utilising coal with a calorific value much lower, and an ash content much higher, than was the case previously.

Generally, but not exclusively, coal is stored in open conditions on unlined ground. Since some of the power stations included in the present study intend to make use of mine and other wastes as a component of fuel, the possibility of contamination of surface waters and ground with materials such as heavy metals and polyaromatic hydrocarbons (PAH) cannot be ruled out. The use of front-end loaders for moving coal to the conveyors, even where the storage sites are lined, may exacerbate any contamination of underlying soils and ground waters. At the same time, the move to use of coal with a much higher proportion of fine material may tend to reduce the penetration of surface waters into the underlying soil.

Since coal is stored in open areas, any surface water moving through or off the storage areas may also carry with it coal particles and associated contaminants. Such discharges are currently directed to the power plant cooling reservoirs with, in most cases, little or no treatment prior to disposal. The severity of the impacts of such discharges will depend on the total amount of contaminated water entering the cooling reservoir and the nature of the stockpiled fuel.

Reduction in the use of gas as a fuel where it has been a component, in combination with general reductions in the calorific value of coal available to the power stations leads to an increase in the need for burning of oil. Transfer and storage of such oil also poses potential risks to the environment. The possibility exists of failure of an oil storage tank (as has been the case at one of the sites visited during the present study). The environmental consequences of a spillage of this nature will be conditioned by the level of protection afforded by any containment or treatment system, e.g. the presence and effectiveness of bunds surrounding the tank, the systems for controlling drainage water from the bunded areas, and the effectiveness of mechanical treatment systems for surface waters arising from oil storage areas.

4.3 Discharges to atmosphere

4.3.1 Sources of pollutants

The key factors in considering environmental impacts of discharges to atmosphere are the effects arising from the dispersion and deposition of dust, SO_2 and NO_x. Production of CO_2 is also an issue due to its action as a greenhouse gas leading to global warming

4.3.1.1 Sulphur dioxide, nitrogen oxides and aerosols

The quantities of ash and gases generated during the burning of fuel are highly dependent on the nature of the fuel and the conditions in which it is burnt. The extent to which generated particulates are released to atmosphere is then highly dependent on the nature and efficiency of any scrubbers, bag filters or precipitators included within the control system.

In contrast to aerosols, gases such as SO_2 and NO_x are less readily subject to control; desulphurisation systems can be used to reduce the discharges of SO_2, and low NO_x burners in conjunction with selective catalytic reduction (SCR) can be used to reduce discharges of NO_x. It is not clear to what extent appropriate systems for controlling discharges of dust, SO_2 and NO_x form part of the modernisation programmes for each of the power stations. Current efficiencies for dust removal at the sites visited range from a low of 92-93 % at Zmiev to a high of 98-99 % at Ladizin.

Naturally there are other materials released as a consequence of the burning of coal and other fuel, for example heavy metals (cadmium, zinc, lead etc) and naturally-occurring radionuclides. The extent to which such releases occur and their resultant impact is also highly dependent on the nature and source of the fuel. Given the trend towards greater utilisation of mine wastes as a source of fuel for Ukrainian power plants, such releases and their potential effects cannot be ignored.

Figure 1 provides an indication of estimated discharges to atmosphere from Ukrainian power stations over the period 1997 to 2010 assuming either K2 and R4 NPPs do not operate (alternative option 2) or that they do operate (base case option 1). There is a clear and marked reduction in the discharge of all three pollutants when conventional power generation is assumed to be replaced by nuclear power generation.

The key pollutants can be treated differently because of their impact area. Ash, NO_x and SO_2 are generally of most interest on the local and regional scale whereas CO_2 is of interest on a global scale. Regional and transboundary issues are discussed in Section 4.3.4.

4.3.1.2 Carbon dioxide

Taking the average carbon content of coal to be 800,000 ppm and assuming that the fuels to be burnt contain approximately 40% ash gives a total of 480 kg carbon combusted/te fuel, resulting in 1760 kg CO_2/te fuel.

Assuming 6 million te of fuel is required per year for production of 1800 MW, then for 2000 MW production (i.e. equivalent to both K2 and R4 operating) gives 11.7×10^6 te CO_2 / annum, or, over an operating period of 30 years, approximately 350 million tonnes.

4.3.2 Dispersion and deposition

All the sites included in the present study have stacks of 250 m height. Subsequent dispersion and deposition of SO_2 and NO_x following discharge from the stack is dependent on meteorological conditions, which are specific to individual sites. The impacts of deposited materials are then determined by factors such as location relative to the point of discharge and nature of the habitat. All five sites included in the present study can largely be considered as being in a rural context. Each site is serviced by a local settlement generally 1-2 km distant from the power station itself. Only one site appears to have extensive semi-natural or forested environment in close proximity to it.

Detailed modelling of the dispersion and deposition of pollutants from each site has not been undertaken. However, by reference to studies at other locations and with the proviso that these studies generally relate to a stack height of 100 m rather than the typical 250 m height associated with Ukrainian power stations, it is possible to provide a general indication of the ranges of dispersion factors that might apply. In this context the dispersion factor is defined as the ratio of concentration of a pollutant in air at ground level ($\mu g/m^3$) to discharge rate (g/s). The relevant dispersion factors are summarised in Table 2 and have been obtained taking a range of meteorological conditions into account.

Table 2
Dispersion factors applied in this study

Pollutant	1.5 km	2.8 km	20 km
SO_2	0.01 – 0.2	0.03 – 0.5	0.03 – 0.2
NO_x	0.05 – 0.7	0.03 – 0.5	0.01 – 0.2
Particulates	0.1 – 1	0.1 – 0.7	0.02 – 0.2

This analysis demonstrates that, depending on atmospheric conditions, stack height and other factors, the order of magnitude concentration for a given pollutant at distance (20 km) may not differ from that closer to a site e.g. at 1.5 km. The effect is less marked for particulate matter than for gases.

Appendix B indicates estimated total discharges for Starabeshevo units 5, 6, 8, 9, 10, 11, 12 and 13 in 1997 as follows.

Pollutant	Discharge (tonnes)
Sulphur dioxide	32935
Nitrogen oxides	8902
'Dust'	29045

When combined with ranges of dispersion factors given in Table 2, the above indicate the following ranges of ground level concentrations of different pollutants that might be anticipated at 1.5 to 20 km from a source and in a range of atmospheric conditions.

Pollutant	Concentration range ($\mu g/m^3$)
Sulphur dioxide	10 - 530
Nitrogen oxides	3 - 200
'Dust'	20 - 940

4.3.3 Effects and consequences

4.3.3.1 Particulate matter

The ability of a particle to remain suspended in air depends essentially on its size, shape and density. Large particles fall rapidly, while fine light particles remain suspended for longer. The same properties determine where in the human respiratory tract a particle will land when inhaled so smaller particles tend to penetrate further than larger ones. In general, spherical particles below about 10 µm in diameter have the greatest likelihood of reaching the furthest parts of the lung, the air spaces or alveoli, where delicate tissues involved in the exchange of oxygen and carbon dioxide are to be found. Particles larger than 10 µm, up to about 20 µm, may be deposited in the nose, throat and airways of the lung. The most common method of sampling particles in air relies on the use of a size-selective sampler collecting 50% of particles of 20 µm aerodynamic diameter, 95% of 5 µm particles and only 5% of 20 µm particles. The resulting mass of material is known as PM_{10}.

Growing evidence linking PM_{10} with adverse health effects has made them a priority for regulators. In 1997 the European Commission's working group proposed a 24-hour limit value of 50 $\mu g/m^3$. This figure is identical to the current UK standard based on recommendations put forward in 1995 [5]. However, the WHO declined to put forward a standard on the grounds that it was unable to identify a safe level of exposure. The working group also proposed an annual mean level of 20 $\mu g/m^3$.

Particulate matter is a complex mixture rather than a single chemical compound and, until recently, was studied and controlled in conjunction with SO_2. The particles produced by coal burning lie wholly within the PM_{10} range. Recent studies using the PM_{10} indicator have demonstrated consistent associations between changes in the daily levels of PM_{10} from diverse sources and adverse effects on human health even at concentrations currently encountered within the EC. Some studies in the USA have even indicated that long-term exposure to particulate matter is associated with reduced life expectancy and with chronic effects on lung function.

The many studies which have investigated short-term variations in PM_{10} show risk estimates which are reasonably consistent despite likely differences in the composition of PM_{10} from study area to study area. Since some of the most recent studies suggest that health effects may be associated with smaller fractions of PM_{10} and strong aerosol acidity or sulphates, and that there is no threshold below which effects can be observed even from short-term exposure, the WHO in revising the Air Quality Guidelines for Europe did not derive guidelines for short-term exposure to PM_{10}. In their October 1997 proposal [6], the EC recommended limit values in the range 10 to 50 $\mu g/m^3$ PM_{10} according to the time period for exposure and the number of exceedances occurring within a year.

The calculations presented in Section 4.2.2 for 'dust' clearly provide concentrations (20-940 $\mu g/m^3$) that are well in excess of these guidelines and limits. Such concentrations, in combination with aerosol acidity, can be expected to impact on human health.

Results of regular atmospheric monitoring of 54 Ukrainian cities and towns in 1994 using 173 fixed and 3 mobile stations in comparison with annual average and single maximum allowable concentrations (MAC) have shown that 13 cities exhibit high levels of air pollution [7]. These are mostly located within the Donetsk-Pridniprovsky industrial area. Air pollution in these cities is due mainly to high concentrations of particulate matter and NO_2, with average concentrations of both exceeding MAC thresholds by a factor of 1.3. For all 54 cities, the average annual and maximum individual concentrations of particulate matter were 200 and 3300 $\mu g/m^3$ respectively. The maximum concentration for 'dust' estimated in the present study therefore appears to be significant even when set against what appear to be typical values for particulate matter in urban environments in Ukraine.

Discharges of particulate matter from burning of coal also lead to the soiling of buildings and other materials and may be of significance in urban areas affected by any discharge.

4.3.3.2 Sulphur dioxide

Sulphur is naturally present in coal and oil, and is derived from the proteins present in the tissues of plants and other organisms from which coal and oil are formed. When coal and oil are burnt in power stations the sulphur is oxidised to sulphur dioxide and, in the absence of suitable abatement measures, released to the atmosphere. Sulphur dioxide is one of the principal pollutants that causes acidification. In addition, sulphur dioxide, together with other pollutants contributes to the formation of suspended particles (above) which are now recognised as having a significant impact on human health.

Sulphur dioxide is directly toxic to humans. It acts on the mucous membranes of the mouth, nose and lungs and its main impact is on respiratory function. Asthmatics are particularly sensitive. Through its effects on respiratory function it can also impact on cardiovascular conditions. Elevated levels of SO_2 can also be damaging to plants, both natural vegetation and agricultural crops. Damage of membranes and inhibition of photosynthesis are the most frequently reported effects in plants which are most sensitive to exposure in winter when suffering other stresses. Sulphur dioxide can also accelerate the natural weathering and corrosion of buildings and building materials.

For SO_2 the WHO ten minute average is set at 500 $\mu g/m^3$ and the one hour average is set at 350 $\mu g/m^3$. WHO guidelines are more stringent that EC limit values, which were established by EC Directive 80/779 which came into force in 1983. In the UK a standard of 100 ppb was recommended in 1995 measured over a fifteen minute averaging period. This recommendation was adopted in 1997 with a provisional objective to achieve the standard at the 99.9th percentile level by the year 2005. WHO and ENECE have recommended different critical levels for protection of crops, natural vegetation, and lichens. To take account of different sensitivity under winter conditions, these critical levels must be met both as an annual and winter mean. In the UK, a daily limit of 125 $\mu g/m^3$ and annual mean limit of 20 $\mu g/m^3$ have been proposed to protect ecosystems, with an even tougher limit of between 10-15 $\mu g/m^3$ to protect zones where there are monuments sensitive to SO_2 damage.

In the October 1997 EC proposal on air quality [6], limit values in the range 125 to 350 $\mu g/m^3$ are proposed for protection of human health according to the period of exposure and the frequency of exposure. A single concentration of 20 $\mu g/m^3$ is proposed for protection of ecosystems, measured over two averaging periods: the calendar year and the winter period October to March.

The range of concentrations estimated in the present study (10-530 $\mu g/m^3$) encompasses the limit values discussed above and could therefore be expected to impact on both human health and ecosystem functioning.

Results of monitoring in Ukrainian cities and towns in 1994 [7] indicate average annual and maximum concentrations of SO_2 in 52 cities and towns of 200 and 1969 $\mu g/m^3$ respectively. Ten percent of the cities and towns studied exceeded the relevant MAC. The maximum concentration of SO_2 estimated in the present study therefore appears to be significant even when set against what appear to be typical values for particulate matter in urban environments in Ukraine.

The potential effects of both particulate matter and SO_2 on human health must be viewed in the light of what is currently reported to be a deteriorating situation regarding health statistics in Ukraine [7].

4.3.3.3 Nitrogen oxides

There are many different oxides of nitrogen, formed chiefly by the oxidation of nitrogen in air during combustion. The pollutant species of most interest from the point of view of human health is nitrogen dioxide (NO_2). It is associated with a number of adverse effects, including increased risk of respiratory infection in children and effects on lung function, particularly in those with pre-existing lung disease. Both NO_2 and NO are absorbed by vegetation. Their effects on plants are additive and the scientific consensus is that they should be treated together. Nitrogen is an essential plant nutrient. Low exposures to NO_x can promote growth whereas higher exposures can cause adverse effects including needle or leaf damage and reduced growth.

The air chemistry of NO_2 is complex. In most situations, primary emissions from combustion consist predominantly of NO. This then reacts with oxygen or ozone to produce NO_2, with the proportion converted depending on atmospheric conditions. Some NO_2 is removed from the air by dry deposition and some will eventually be removed as acid deposition (see below). It is also one of the pollutants that leads to the formation of small atmospheric particulates which are themselves associated with adverse effects on human health.

For NO_2 the WHO hourly average limit is set at 200 $\mu g/m^3$ and the annual limit is set at 40 $\mu g/m^3$. These are the same limits as suggested by the October 1997 EC proposal [6]. In the UK the limit proposed to protect sensitive ecosystems is set at 30 $\mu g/m^3$, a figure which is also recommended by WHO for protection against ecotoxic effects for the majority of plant species. WHO has proposed revised guidelines which take into account the lowest observed effect on asthmatics and allow for a further level of protection. The range of concentrations estimated in the present study (3-200 $\mu g/m^3$) approaches the hourly limit discussed above but encompasses the more stringent annual limits for human health and protection of ecosystems. Predicted NO_x discharges could therefore be expected to impact on both human health and ecosystem functioning.

Results of monitoring in Ukrainian cities and towns in 1994 [7] indicate average annual and maximum concentrations of NO_2 in 52 cities and towns of 40 and 690 $\mu g/m^3$ respectively. Seven percent of the cities and towns studies exceeded the relevant MAC. The maximum concentration of NO_2 estimated in the present study therefore appears to be significant even when set against what appear to be typical values for particulate matter in urban environments in Ukraine.

Increased atmospheric deposition of nitrogen, in either the oxidised or reduced form, can lead to the development of nutrient imbalances and, in sensitive soils, to soil acidification and to the mobilisation of potentially toxic aluminium. The consequences of deposition of NO_2 can be measured by relating estimates of deposition to 'critical loads'. The critical load is defined as the maximum rate of deposition per unit area of a given type of ecosystem that can be endured indefinitely without adverse effects taking place. To undertake a critical loads analysis would require detailed modelling of the dispersion and deposition of NO_2 at individual sites and comparison with estimated critical loads for the ecosystems surrounding each site. This has not been done in the present study due to the lack of basic information required to calculate critical loadings and the generic nature of the study. Nevertheless it should be noted that, according to the rate of deposition, inputs of nitrate to some ecosystems can have both beneficial and detrimental effects. This is particularly true for agricultural systems which may currently be receiving less than optimal inputs of fertiliser as might be expected to be the case in some areas of Ukraine.

4.3.3.4 Regional and transboundary effects

As well as the local environmental impacts of discharged particles and gases there are also regional or transboundary effects associated with the burning of coal. These include acid deposition, the precursors of which are SO_2 and NO_x.

Europe, with 13% of the world's population, accounts for about 25% of global SO_2 and NO_x emissions. Emissions of these gases from power plants contribute most to total acid deposition (30 to 55%). Nitrogen oxides are providing a growing contribution to environmental acidification. The Convention on Long-range Transboundary Air Pollution [8] was drafted after a link was confirmed between sulphur emissions in continental Europe and the acidification of Scandinavian lakes and later studies had confirmed that air pollutants could travel several hundred kilometres before deposition and damage occurred. The Convention was the first internationally legally binding instrument to deal with problems of air pollution on a broad regional basis. It was signed in 1979 and entered into force in 1983. Since then it has been extended by five protocols, three of which are relevant to the present study i.e.

- The 1985 Protocol on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at least 30 percent.
- The 1988 Protocol concerning the Control of Nitrogen Oxides or their Transboundary Fluxes.
- The 1994 Protocol on Further Reduction of Sulphur Emissions.

In addition, in 1996, the Executive Body started negotiating three new protocols including one on Nitrogen Oxides and Related Substances.

The Protocol concerning sulphur emissions adopted in Helsinki in 1985 and in force since 2 September 1987 has been ratified by 21 Parties. Taken as a whole, the 21 Parties to the 1985 Protocol reduced 1980 sulphur discharges by 52% by 1993. Also five non-Parties had achieved sulphur emission reductions of 30% or more. These reductions had been either maintained or further reduced by 1995.

The Protocol concerning nitrogen oxides adopted in Sofia in 1988 and in force since 14 February 1991 has been ratified by 25 Parties. Nineteen of the 25 Parties to the 1988 Protocol have reached their target of stabilised emissions at 1987 levels and eight Parties have reduced emissions by more than 25%. Seven of these are countries with economies in transition. Ukraine is amongst those countries which had succeeded in stabilising their emissions at 1987 levels by 1994.

National anthropogenic emissions reported by Ukraine to the Convention on Long-range Transboundary Air Pollution based on data received by 31 May 1997 include the following.

	Emission (thousands of tonnes)						
Pollutant	1989	1990	1991	1992	1993	1994	1995
Sulphur	3073	2782	2538	2376	2194	1715	1639
Nitrogen dioxide	1065	1097	989	830	700	568	530

The power station emissions data for 1997 reported in Appendix B indicate totals in the order of 1200 thousand tonnes for SO_2 and of 300 thousand tonnes for NO_x. Comparing these to the figures given above for 1995 indicates contributions from the power stations considered in Appendix B to the total emissions for Ukraine in the order of 75% for SO_2 and 56% for NO_2. The increase relative to the base case i.e. no modernisation is in the order of 6 to 11% for ash, SO_2 and NO_x (Figure 1). Given the fact that discharges are projected to increase with refurbishment of selected power stations and the fact that there will be a drive to reduce emissions overall to meet the requirements of existing Protocols, it is quite clear that the selected power stations will remain significant contributors to total emissions of both SO_2 and NO_x.

Overall, in 1994 the major share of emissions of pollutants from fixed sources in Ukraine (32%) was stated to be accounted for by power plants [7]. Also an increase in emissions relative to 1993 was reported in selected areas of Ukraine, including Kharkhiv and Donetsk, due to a deterioration in the fuel balance including increased use of coal and heavy fuel oil.

Total CO_2 emissions data for Ukraine have not been reported to the Convention. The annual estimated CO_2 production for 2000 MW of generation of approximately 12 million te (above) can therefore not be compared and contrasted with the country's total emissions but can be expected to be a significant contributor to those emissions.

4.3.3.5 Other impacts

In addition to atmospheric pollution arising from the burning of coal, the potential exists for releases of contaminants to atmosphere as a consequence of transformer fires. Such events are, luckily, very infrequent. The severity of their impacts depends very much on the nature of the oils being used in the transformers and whether or not they contain PCB additives.

4.4 Production, storage, utilisation and disposal of ash and slag

Reduced calorific value of fuel and increased ash content, coupled with improvements to the methods used to remove dust from the atmospheric discharge all result in increased quantities of ash and slag which require suitable disposal.

In general, the routes for re-utilisation of ash from coal-fired power generation in Ukraine have declined both because of the declining quality of the ash produced and the lack of suitable markets for its utilisation. Ash is generally transferred to storage areas as a slurry where it is left to settle in lagoons. After settlement, the ash forms a material which can be used as a building material to extend the bunds of the lagoons. The extent to which ash can be disposed of depends on the area of land available for operating the settlement lagoons. Since the lagoons need to be relatively extensive, it is often the case that disposal cannot take place close to the source of production because of the quality of the surrounding land or the nature of the topography.

Slag, i.e. the material that accumulates within the furnaces, generally accumulates those contaminants, which are either not destroyed at, or vaporised by, the temperatures used to operate the furnaces. It appears to be general practice in Ukraine to combine slag with ash. It is important to note that if contaminants have not been destroyed or removed during the burning process then it is unlikely that they will become biologically available in the disposal lagoons. As the water content of the material decreases with time and becomes more stable, the possibility of mobilisation of contaminants is further reduced.

The main impacts associated with ash disposal are, therefore:

- The land area required to provide the disposal facility.
- The potential for release of slurry due to a failure in the pipework, in the pumping system linking the power station with the disposal site, or dam failures of ash lagoons.
- Migration of contaminants from the disposal site into surrounding soils and groundwater.
- Dust arising from disposal lagoons.

Such impacts can generally be mitigated by good environmental management practice e.g. revegetation of disused lagoons.

4.5 Water supply, treatment and disposal

Any power station is a major source of waste heat, which is generally dissipated to atmosphere either through cooling towers or via a cooling reservoir. At the sites considered in the present study only one has the option to make use of cooling towers in addition to a reservoir. In all cases the reservoirs have been designed specifically for the purpose of providing a mechanism for dissipating heat.

The increased temperature of the reservoir leads to an increase in productivity, the effects of which are generally managed for example to assist with fish farming. Nevertheless, a careful balance has to be struck between the engineering requirements for water supply and biological conditions in the reservoir. Any significant discharge of contaminants to the reservoir either through disposal of process waters or surface water run off, may have substantial consequences for the local aquatic ecosystem.

4.6 Noise

Power stations are a significant source of noise as a consequence of coal handling, steam generation and operation of the turbines. The location of the power stations included in the present study relative to the main population centres is such that the consequences of noise off-site are likely to be of little practical significance.

4.7 Socio-economic factors

Each power station supports an associated settlement with a population in the range 10,000 to 25,000. Modernisation and continued operation of any of the power stations will therefore lead to a positive socio-economic impact, at least locally. On the other hand, discharges from the power station will impact on the population which benefits economically from its presence.

4.8 Other

There are potential impacts arising during reconstruction and modernisation of the power plants. Removal of existing equipment will result in solid wastes requiring re-utilisation or disposal. The impacts of increased traffic flows may also need to be considered.

5.0 DISCUSSION AND CONCLUSIONS

Modernisation and increased use of coal fired power stations in Ukraine as an alternative to completion of the K2 and R4 nuclear power plants will result in a number of adverse environmental impacts, some of which have been considered here. Whereas the effects of some can be mitigated by good environmental management, there are others which are less amenable to mitigation and which may have irreversible consequences for man and the environment.

In the EU the energy sector is responsible for a large contribution to the emissions of CO_2 (33%), NO_x (20%) and SO_2 (60%) and furthermore contributes to a large extent to the emissions of particulates (40-55%) [9]. The emissions are mainly caused by power plants and refineries. These emissions contribute to the environmental problems of climate change, acidification and urban air quality. In Ukraine, energy generation is also a major source of CO_2 and of other pollutants such as SO_2, NO_x and particulate matter. The non nuclear least-cost option to K2/R4 would involve increased overall emissions of CO_2, SO_2, NO_2 and particulate matter. For SO_2 and NO_2, all indications are that the non nuclear least-cost option would increase Ukraine's total emissions by approximately 10%. This would occur at a time when there is great international pressure and agreement to reduce substantially emissions of both SO_2 and NO_x. In very broad terms, it appears that the non nuclear least-cost option may increase Ukraine's emissions of CO_2 by between 8 and 10%.

On a more local scale, all indications are that the non nuclear least-cost option would result in concentrations of SO_2, NO_2 and particulate matter in ground level air close to, or in excess of, limits applied elsewhere in the world including the EU. For SO_2 and particulate matter the main impact could be expected to be on human health of the locally resident populations, a situation that would be exacerbated by the combination of exposure to particulates and to acidity. Whereas increased exposure to NO_2 will also impact on human health, the main concern will be with respect to impacts on soils and vegetation given the typical site context of the power stations considered in the present study.

Apart from the effects of emissions of air pollutants, the non nuclear least-cost option would result in impacts arising from extraction, transport and storage of raw materials, from the disposal or utilisation of ash and slag, and from the discharge of process and other waters. The majority of these impacts can be mitigated by the introduction of appropriate health, safety and environmental management systems and an associated system of monitoring of actual versus predicted impacts.

It is not possible to draw a direct comparison between the environmental impacts of the non nuclear least-cost option and those associated with completion of the K2 and R4 nuclear power plants. In the case of the non nuclear least-cost option the main impacts are those associated with human health on a local scale (say up to 30 km from the source) for which there is currently no direct measure of risk, and no exact measurement of total emissions of key pollutants to atmosphere for which international agreements apply, and actual local impacts on soils and vegetation for which detailed quantitative studies would be required on a site-by-site basis. In the case of the K2/R4 project the main concern is with the probability of a serious accident occurring and the subsequent risks to man and the environment as a consequence. However the K2/R4 project allows not only for completion of the respective nuclear power units but also for upgrading of their safety levels to levels required for similarly aged plants recently re-approved in the West. This safety upgrading will reduce the probability of a serious accident occurring. In contrast to the non nuclear least-cost option, the environmental impact of either K2 or R4 during normal operation is considered to be of relatively small significance

6.0 REFERENCES

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Appendix A

TERMS OF REFERENCE

Appendix B

SAMPLE DATA PROVIDED BY EPRI

The following Table provides a sample of data for discharges of various pollutants from Ukrainian power stations for 1997 as provided by the Electric Power Research Institute and used to provide a basis for the calculations given in the main text.

Unit name	SO_2 Emissions (ton)	NO_x Emissions (ton)	Ash Emissions (ton)
Burshtyn 5-12	92567	26823	82649
Kurakhov	134235	28404	122390
Ladizhin	64362	19143	34583
Zuev	104480	23547	95261
Krivoj Roj 7-10	104183	22279	94991
Lugansk 12-15	729	187	392
Lugansk 6-7	13	2.6	6.8
Mironov 1	132	27	118
Mironov 2	525	106	469
Pridneprovii 14	64165	18145	57290
Pridneprovsk 7	8334	2342	7441
CHP 10	0	2	0
Slavyansk 1	0	7.4	0
Slavyansk 2	46	9.2	41
Starabeshevo 6	5890	1592	5259
Tripoli 1-4	77308	22822	69025
Tripoli 5-6	330	71	0
Zmiev 7-10	59320	17382	52964
Zmiev 2,4,6	10220	2718	9125
Uglegorsk 1-4	103609	23547	94467
Uglegorsk 5-7	495	108	0
Zaporozhe 1-4	75170	23547	67116
Zaporozhe 5-7	0	2111	0
Dobrotvorsk 7	709	105	646
Dobrotvorsk 4	450	67	410
CHP 11-20	0	1	0
CHP 21-30	0	0.5	0
Kharkov 1-2	0	0.7	0
Kharkov 3	0	2	0
Kiev5 1-2	3	2	0
Kiev5 3-4	13	10	0
Kiev6 1-2	10	7.5	0
Krivoj Roj 1	26012	5563	23717
Krivoj Roj 2	25995	5559	23701
Krivoj Roj 3	25973	5554	23682
Krivoj Roj 4	25947	5549	23657
Krivoj Roj 5	25914	5542	23627
Krivoj Roj 6	25873	5533	23590
Lugansk 8	327	84	176
Lugansk 9	297	76	159

Unit name	**SO_2 Emissions (ton)**	**NO_x Emissions (ton)**	**Ash Emissions (ton)**
Pridneprovsk 8	8276	2325	7389
Pridneprovsk 9	8212	2307	7332
Pridneprovsk 10	8148	2289	7275
Starabeshevo 7	5744	1553	5128
Burshtyn 1	12219	3541	10910
Burshtyn 2	12156	3523	10854
Burshtyn 3	12089	3503	10793
Burshtyn 4	12017	3483	10730
Dobrotvorsk 5	430	64	392
Dobrotvorsk 6	412	61	376
Dobrotvorsk 8	583	87	532
Lugansk 10	268	69	144
Lugansk 11	243	62	130
Starabeshevo 9	4422	1195	3948
Starabeshevo 11	4124	1115	3682
Zmiev 1	3253	865	2904
Zmiev 3	3171	844	2832
Starabeshevo 5	4031	1090	3599
Starabeshevo 10	3767	1018	3363
Starabeshevo 8	3652	987	3261
Starabeshevo 12	3568	964	3185
Starabeshevo 13	3481	941	3108
TOTAL	**1177899**	**300461**	**1038819**