## 10. THE BASE CASE ALTERNATIVE

As noted in Section 1, EBRD environmental procedures require a comparison of impacts from the proposed project, i.e. completion and upgrading of R4/K2 and closure of the Chornobyl NPP, with the base case, i.e. the current situation with Chornobyl Unit 3 in operation and the possibility of both Units 2 and 3 operating. This Section provides a brief introduction to the state of the power industry in Ukraine in the last few years (Section 10.1) as a prelude to a discussion of such a comparison (Section 10.2).

### 10.1 Power generation and the nuclear contribution 1991-1995

Ukraine became independent in 1991 and immediately experienced a severe recession. Gross domestic product (GDP) fell from the equivalent of US$ 155.6 billion in 1990 to US$ 68.8 billion in 1995 (both at 1990 prices), a large balance of payments deficit developed (US$ 1.2 billion in 1995) and inflation became rampant [10.1]. Primary energy consumption mirrored the slump in the economy by dropping rapidly from 1991 to 1995 (Table 10.1). Ukraine has a once-large but declining coal industry. In addition to the decline in production (from 131 Mt in 1991 to 66 Mt in 1995) the quality of the coal being mined also declined. The country became a net importer of coal in 1992 and relies heavily on imported oil and gas from Russia (e.g. 66 billion m$^3$ of gas and 13 Mt of oil from Russia and Turkmenistan in 1995).

**Electricity generation in Ukraine from different sources**

| Plant type | (MW) | Generation in 1991 (GWh) | Load factor in 1991 (%) | Generation in 1995 (GWh) | Load factor in 1995 (%) |
|---|---|---|---|---|---|
| Coal/dual fired | 32,000 | 183,000 | 65 | 107,000 | 38 |
| Nuclear | 13,000 | 75,000 | 66 | 71,000 | 62 |
| Hydro | 5,000 | 12,000 | 27 | 10,000 | 23 |
| Industrial | 2,000 | 7,000 | 40 | 5,000 | 29 |
| **Total** | **52,000** | **277,000** | | **193,000** | |

As coal output from the country's mines peaked in the late 1970s a programme to supplement the country's thermal plant with new nuclear stations began. This resulted in work on 16 new reactors being started between 1978 and 1990, all but two of which (K2 and R4) have now been completed. Although the installed generating capacity in 1995 was 52,000 MW the effective capacity was only about 50,000 MW due to the derating of older plants. In 1995, approximately half of the 40 plus thermal plants were over 30 years old and approximately 23,000 MW of these ageing coal plants had to use fuel oil or gas as supplementary fuel to operate. In 1995, 14 nuclear plants, including those at Chornobyl, provided 13,000 MW of nuclear capacity. A collapse in output from thermal power plants (which roughly halved from 1991 to 1995) created an ongoing need for electricity from Chornobyl. The average load factor for other nuclear power stations was approximately 61% against a design benchmark for VVER reactors of around 85%.

## 10.2 The base case

The base case alternative to completion and modernisation of K2 and R4 is continued operation of Chornobyl Unit 3 and possibly even restart of Unit 2. This Section provides background information on the Chornobyl site, the history of operation of the RBMK reactors at the site, and a summary of the environmental and radiological impacts of the accident that occurred in 1986. It provides background for a discussion on the likely environmental and radiological implications of continuing operation of the Chornobyl NPP. This discussion considers both routine discharges and the potential consequences of a further major accident.

### 10.2.1 The Chornobyl NPP site

The Chornobyl NPP is situated in the eastern part of the Ukrainian Polissa, alongside the River Pripyat, a tributary of the Dnieper (Fig. 10.1). It is in the North of Ukraine some 10 km from the border with Belarus and approximately 120 km from Kyiv. The area is a flat plain approximately 200 m above sea level with minor slopes. It is characterised by a moderate continental climate with hot summers and rather mild winters; annual precipitation ranges from 500 to 650 mm, of which approximately two thirds occurs during the warm seasons.

Topsoils in the south of the Belarus Republic consist of mainly of soddy-podzols and swampy peat soils; in the southeast they consist of soddy-podzol, clay and sandy soils [10.2]. The Polissa is principally characterised by swampy sandy and clayey-sandy soddy-podzols and peat bogs. Light textured soils occupy 58% of the total area. All soddy-podzols exhibit a low natural fertility, low pH (between 5 and 5.5) and are characterised by low nutrient content and low sorption capacity. Seventy percent of the area is occupied by forests with conifers (pine) representing the most common species (63%) and deciduous trees (oak, white beech, birch and alder) the remainder. Agricultural activities are represented mainly by dairy farming and meat production. About one quarter of the area is devoted to agriculture, half of it being used for production of fodder (natural meadows). Cultivated lands are principally used of cereals (about 50%), fodder crops (35 to 40%), potatoes (8%) and flax (5%).

In the Ukrainian Polissa there is an area of forest steppe where the topsoil consists primarily of podzolised black earth (chernozem) and grey/light-grey soils on forest litter. The main tree species in the Ukrainian Polissa are pines with some birch and oaks; the forest steppe is characterised by oaks, white beech and lime trees.

## Figure 10.1
## The Chornobyl site

The cooling pond for the NPP is connected to the Pripyat but is maintained at a higher level than the Pripyat.

Countermeasures introduced after the accident of 1986 caused considerable disruption to the environment with major changes introduced to the hydrology and land use. Additionally, the exclusion zone established in 1986 has been extended in recent years to include the Poliske District; it is understood that there have been plans to lift restrictions in other areas.

### 10.2.2 The RBMK reactor

The RBMK reactor is a graphite-moderated pressure-tube type reactor. It is cooled by circulating light water that boils in the upper parts of vertical pressure tubes to produce steam. The steam is produced in two cooling loops, each with 840 fuel channels, two steam separators, four coolant pumps and associated equipment. The steam separators supply steam directly to two 500 MW(e) turbogenerators, each with a condenser and feedwater system. The reactor is refuelled whilst operating.

A major part of the coolant circuit is enclosed in a series of strong containment rooms. These are connected to water-filled suppression systems below the reactor to capture and condense steam that might be released in the containment rooms by any leakage of coolant. A notable exception is the upper part of the reactor, especially refuelling end-caps on channels above the core.

At equilibrium fuel irradiation, the RBMK reactor has a positive void reactivity coefficient. However the fuel temperature coefficient is negative and the net effect of a power change depends on the power level. Under normal operating conditions, the net effect (power coefficient) is negative at full power and becomes positive below approximately 20% of full power. Operation of the reactor below 700 MW(th) is restricted by operating procedures owing to the problems associated with maintaining thermal-hydraulic parameters within their normal operating range.

The RBMK reactor includes 211 absorbing rods which are used to control the global and spatial power distribution and for emergency protection. Emergency protection is provided by insertion of all absorbing rods.

The Units are generally built in pairs with each Unit occupying opposite sides of a single building complex and sharing some plant systems. The usual operating lifetime is 25 years.

However, the reactor's graphite moderator distorts under neutron irradiation such that, after approximately 15 years of operation, the pressure tubes in the reactor have to be cut and the graphite fuel channels rebored.

The history of RBMK type reactors in terms of electricity generation in the Soviet Union before 1986 had been rather satisfactory. After early development of the system, the Soviet Union went directly to full scale 1000 MW(e) Units. As a result of the examination performed within the framework of the "RBMK Safety Review Project", which for the largest part was financed by the TACIS programme of the European Union after the Chornobyl accident, it was determined that the RBMK concept, apart from its safety deficits (Section 10.2.6.3.), also has some advantages [10.10] such as:

I. the maximum specific rod power is relatively low;
II. the possibility for exchange of defective fuel elements during normal operation;
III. the large heat capacity of the graphite; and
IV. the potential for accident management measures.

### 10.2.3 History of developments at the Chornobyl NPP prior to 1986

Construction of the Chornobyl NPP was carried out in three stages, with each stage comprising two RBMK 1000 Units. Construction of Units 1 and 2 started in 1970 with commissioning in 1977. Construction of Units 3 and 4 was completed in late 1983, and in 1981 construction of two further Units was started at a site 1.5 km to the south east of the existing site. A pond of 22 $km^2$ area was constructed to provide cooling water for the turbine condensers and other heat exchangers of the first four Units.

Unit 1 was subject to a fuel failure in 1982. However Unit 4, one of 15 RBMK reactors brought into operation in the Soviet Union, operated very successfully for three years prior to a catastrophic accident in 1986 (below).

### 10.2.4 The 1986 accident - cause and subsequent changes to design

On 26 April 1986 an accident occurred at Chornobyl Unit 4 resulting in destruction of the reactor core and part of the building in which it was housed. The IAEA and the Soviet Union agreed to hold a post-accident review meeting in Vienna over the period 25-29 August 1986. At this meeting leading Soviet scientists and nuclear engineers presented a report providing basic technical information on the NPP, an account of the causes of the accident, the accident sequence, its consequences and the countermeasures that were taken. The International Nuclear Safety Advisory Group (INSAG) was then requested to prepare a report on the basis of the meeting and the discussions that had taken place [10.3]. The original report was subsequently updated in 1992, specifically with respect to the cause of the accident and material that had become available subsequent to the original post-accident review [10.4].

The accident occurred during a test on a turbogenerator at the time of normal scheduled shutdown of the reactor. This was intended to test the ability of a turbogenerator, during station blackout, to supply electrical energy for a short period until the standby diesel generators could supply emergency power. To provide appropriate conditions for the test, the reactor was at low power (200 MW(th)) in coolant flow rate and cooling conditions which could not be stabilised by manual control. Most of the control rods were withdrawn and some important safety systems were voluntarily switched off. The subsequent events lead to an increasing amount of steam voids in the reactor core, thereby increasing positive reactivity. The start of a period of increasingly rapid rise in power was observed and a manual attempt made to stop the chain reaction. The automatic trip, which the test would have triggered earlier, had been blocked. The possibility of a rapid shutdown was limited since almost all the control rods had been withdrawn completely from the core.

The continuous reactivity addition by void formation led to a super-prompt critical excursion. It has been calculated that that the first power peak reached 100 times the nominal power within four seconds.

Energy released by the power excursion ruptured part of the fuel into minute pieces. The small hot fuel particles and possibly evaporated fuel then caused a steam explosion (simultaneous rupture of numerous pressure tubes).

The energy released shifted the 1000 te reactor cover plate and resulted in all cooling channels on both sides of the reactor being cut. After two or three seconds a second explosion was heard and hot pieces of the reactor were ejected from the destroyed building. Destruction of the reactor allowed the ingress of air that subsequently led to burning of the graphite.

Radiological and environmental consequences of the accident are summarised in Appendix E.

Most analyses associate the severity of the accident with defects in the design of control and safety rods in conjunction with the physics design characteristics, which permitted the inadvertent setting up of large positive void coefficients. The scram just before the sharp rise in power that destroyed the reactor may well have been the decisive contributory factor. However, the features of the RBMK reactor had also set other pitfalls for the operating staff, any of which could well have caused the initiating event for the accident or for almost any other identical event. INSAG therefore concluded in 1992 that the accident could be seen to be the result of a concurrence of the following main features.

- Specific physical characteristics of the reactor.
- Specific design features of the reactor control elements.
- The fact that the reactor was brought to a state not specified by procedures or investigated by an independent safety body.

It was also noted that operating staff at Chornobyl were not aware of the nature and cause of an earlier accident at Leningrad Unit 1 (that had occurred in 1975) which had already indicated major weaknesses in the characteristics and operation of RBMK Units.

Despite the above, INSAG stated that it was not known for certain what started the power excursion that destroyed the Chornobyl reactor. They further concluded that the accident had flowed from deficient safety culture, not only at the Chornobyl NPP, but throughout the Soviet design, operating and regulatory organisations for nuclear power that existed at that time.

INSAG noted that it had been reported that organisational and technical measures to improve the operating safety of RBMK reactors were developed immediately following the Chornobyl accident. These included placing restrictions on the remaining RBMK plants, the implementation of changes that had earlier been seen as necessary, and other measures that were clearly beneficial in terms of safety. These measures were aimed at:

- Reducing the positive steam (void) coefficient of reactivity and the effect on reactivity of the complete voiding of the core.
- Improving the speed of the scram system.
- Introducing new computational codes for the operational radiation monitoring (ORM), with numerical indication of ORM in the control room.
- Precluding the possibility of bypassing the emergency protection system whilst the reactor is at power, through an operating limit requirement and the introduction of a two key system for the bypass action.
- Avoiding modes of operation leading to reduction of the departure from nuclear boiling margin for the coolant at reactor inlet.

Reduction of the void coefficient of reactivity had been stated to have been provided by the installation of additional fixed absorbers (up to 90 pieces) into the core, and through introduction of 2.4% enriched uranium fuel in all RBMK reactors. Existing control and safety rods were stated to have been replaced by new ones of an improved design which would not leave water columns towards the bottom and which had longer absorbing sections. Also that the speed of insertion of control and safety rods had been increased with the time for full insertion into the core being reduced from 18 s to 12 s, and that 24 additional safety rods had been installed at all operating reactors.

Nethertheless, the following modifications that are required for improving the nuclear safety of the RBMK reactor design have not yet been fully implemented at Chornobyl Unit 3.

- The original design was able to sustain a rupture of one fuel channel without damage to the reactor head structure. The post accident safety modification was designed to provide the ability to sustain up to nine simultaneous fuel channel failures. This modification is only partially implemented at Unit 3, allowing the head structure to accommodate the rupture of three or four fuel channels.
- The modifications needed to reduce the positive coefficient reactivity during a transient have not yet been implemented completely (partial implementation of the new poison rod assemblies, of the modified control rods, and of the higher enrichment fuel assemblies).
- The fire protection improvement measures have not yet been fully implemented.

### 10.2.5 History and developments at the Chornobyl NPP since 1986

The Chornobyl NPP has had a chequered history since 1986 with periodic attempts to close and re-open the site. Following the 1986 accident, operation of Units 1 and 2 was resumed in October/November 1986. Operation of Unit 3 resumed in December 1987 but in an increased radiation environment due to the neighbouring destroyed Unit 4. In 1991, a fire in the turbine hall of Unit 2 led to the collapse of the turbine hall roof and severely damaged a number of vital safety systems. This precipitated a moratorium on nuclear development in Ukraine. In 1993 this moratorium was cancelled and, in December 1993, due to the economic and energy crisis in Ukraine (Section 10.1) 2% enriched fuel needed to be used from the shutdown Unit 2 instead of the 2.4% enriched fuel which had been required since the 1986 accident [10.4].

Over the period 7 to 17 March 1994, an international safety assessment expert mission visited the Chornobyl NPP to review safety at the site following the decision by Ukraine to continue operation of the NPP. The mission found such serious safety deficiencies at the site such that the IAEA's Director General wrote to the President of Ukraine informing him that international safety levels were not being met [10.5]. A further IAEA mission visited the Chornobyl site over the period 11-22 April 1994 as part of the Assessment of Safety Significant Event Team (ASSET). This mission focused on an analysis of operating events and how they were handled by the NPP staff. Overall, the mission found the NPP staff "to be talented and dedicated to safe operation of their facility" and reported no significant deviations from patterns at other RBMKs.

In its Annual Report for 1995 [10.6] the IAEA stated that, for RBMK plants, the most relevant issues were: the safety culture as an underlying basis for operation; void reactivity associated with the loss of coolant from the channels of the control and protection system; independent and diverse reactor shutdown; demonstration of the applicability of the leak before break concept; volume and procedures for in-service inspection; and fire safety. In the identification and ranking of the RBMK issues, the results of an international project to investigate the safety of design solutions and the operation of nuclear power plants with RBMK reactors, funded by the EC and partially completed in early 1995, had been taken into account.

Since that time, further improvements in safety systems and safety culture have been implemented at the Chornobyl NPP but, as presented in Section 10.2.4, some modifications have not yet been fully implemented and arguments concerning closure have continued. One of the arguments for closure is the risk of a further catastrophic accident. One of the arguments for continuing operation is that several years of operation are required to make financial provision for the early stages of decommissioning.

At the time of writing the restart of Unit 3 had been further delayed due to the discovery of weld cracking in associated pipework [10.7].

### 10.2.6 Environmental and radiological impacts of continued operation of the Chornobyl NPP

The base case scenario considered here assumes that Units 2 and 3 of the Chornobyl NPP were to operate for the remainder of their original design lifetimes. In the case of Unit 2 it is assumed that all necessary work to repair damage caused by the fire in the turbine hall is completed. For both Units it is assumed that all modifications to design and operating procedures recommended to date are fully implemented.

There has been no comprehensive environmental assessment of continued operation of the Chornobyl NPP despite the fact that such a study was advocated by the NPP management and several Ukrainian authorities. As a consequence, the following discussion is based on a number of assumptions, several of which will require substantiation if the base case is to be pursued.

#### 10.2.6.1 Routine discharges

On the basis of data for discharges from Khmelnitsky NPP and Chornobyl NPP over the period 1994 to 1996, Table 10.2 provides a comparison of likely average discharges to atmosphere for one VVER-1000 and two RBMK-1000 Units.

**Table 10.2**
**Annual discharges (Bq) from typical VVER-1000 and RBMK-1000 NPPs [10.8]**

| Year | MLN | I-131 | MRG |
|---|---|---|---|
| One Unit (VVER-1000) operating at Khmelnitsky | | | |
| 1994 | 7.6 $10^{7}$ | 1.3 $10^{8}$ | 1.4 $10^{13}$ |
| 1995 | 8.0 $10^{7}$ | 3.0 $10^{8}$ | 5.7 $10^{13}$ |
| 1996 | 9.9 $10^{7}$ | 5.7 $10^{8}$ | 7.4 $10^{13}$ |
| Average for one Unit | 1.7 $10^{8}$ | 6.7 $10^{8}$ | 9.7 $10^{13}$ |
| Two Units (RBMK-1000) operating at Chornobyl | | | |
| 1994 | 6.8 $10^{9}$ | 4.7 $10^{9}$ | 1.7 $10^{15}$ |
| 1995 | 3.7 10 | 5.4 $10^{9}$ | 8.6 $10^{14}$ |
| 1996 | 4.1 $10^{9}$ | 7.8 $10^{9}$ | 6.1 $10^{14}$ |
| Average for two Units | 4.8 $10^{9}$ | 6.0 $10^{9}$ | 1.1 $10^{15}$ |

Notes:
MLN = mixture of long-lived radionuclides
I-131 = sum of gaseous and aerosol phases
MRG = mixture of isotopes of inert gases (Ar, Xe and Kr)
$10^{6}$ Bq = 1 000 000 Bq = 1 MBq
$10^{9}$ Bq = 1 000 000 000 Bq = 1 GBq
$10^{12}$ Bq = 1 000 000 000 000 Bq = 1 TBq

It is clear that the likely discharges from the RBMK option are higher than for the VVER option. The ratios of RBMK discharge to VVER discharge for the different main categories of discharge are as follows.

| | RBMK/VVER |
|---|---|
| Mixture of long-lived radionuclides | 28 |
| Iodine-131 | 9 |
| Mixture of inert gases | 11 |

The predicted individual doses from a VVER-1000 sited at either Khmelnitsky or Rivne are in the order of $10^{-4}$ to $10^{-5}$ mSv per annum and are dominated by exposure to inert gases. Even if these predicted doses were to be increased by a factor of thirty they would still be extremely small relative to the limits applied to members of the public and relative to the natural radiation background.

In 1996, the annual liquid discharge from Chornobyl Unit 2 was 4.7 $10^{10}$ Bq compared with 5.2 $10^{9}$ Bq for the Khmelnitsky NPP (Unit 1) [5.8]

### 10.2.6.2 Accidental discharges

Given the nature of the design of the RBMK, even after the implementation of recommended improvements, the probability of a further catastrophic accident cannot be ruled out. However, the probability of such an event is significantly reduced from that which existed in 1986 due to the overall improvement in safety culture which has been recognised to have occurred. Nevertheless, in the absence of confident PSA results, it should be noted that the

RBMK primary system consists of about 5000 pipes, 3000 flanged joints, 2000 valves and is exposed to graphite contraction [10.10] which contributes to an increase in the probability of a loss of coolant accident or a simultaneous tubes failure, the consequences of which are aggravated by the limited strength of the containment. In the case of the upgraded K2/R4 Units, the core damage frequency will be close to the value for recently reapproved PWRs and significantly lower than the corresponding value for the RBMK. Thus accidental discharges for the RBMK appear to be more likely and potentially more important because of the limited containment than would be those for VVERs.

The overall radiological and environmental impacts of any future accident of this type would clearly be of the same magnitude as that associated with the 1986 accident. However, at least on the local scale, there would be some mitigating circumstances, for example much experience exists on the short and long term management of any accident consequences. Two scenarios of maximum impact can be envisaged.

1) A release to atmosphere which occurs in conditions such that the population of Slavutich is subject to significant exposure.

2) A release to aquatic systems leading to further contamination of the Dnieper.

As concerns the first, the distance of Slavutich from the NPP allows some time for preventive measures to be introduced, for example the distribution of iodine tablets in the event of a significant release of radioiodine or, if necessary, evacuation. The location of Chornobyl with respect to the border with the Belarus Republic is, however, a matter for consideration and appropriate systems would need to be in place to ensure a co-ordinated response to an accidental release.

As concerns the second, the main concern would be collective dose to the population of Ukraine. As was evidenced by the 1986 accident, the opportunity for introducing appropriate countermeasures for aquatic systems is much more restricted than is that for terrestrial systems. The transit period for released radioactivity from Chornobyl to the Kyiv Reservoir is relatively short. As in 1986, measures would be required to provide alternative sources of drinking water, particularly for Kyiv and other cities further downstream, and restrictions would need to be implemented on fishing and the use of water for agricultural activities. Further increases in Sr-90 concentrations in soils of the south of Ukraine receiving irrigation waters or used, for example, for the production of rice, might prove unacceptable.

### 10.2.6.3 Safety issues

Taking into account the results of the 'RBMK Safety Review Project' [10.10] and the fact that Chornobyl Unit 2 belongs to the first generation of RBMK plants and that Chornobyl Unit 3 belongs to the second generation, the most important design deficits of RBMK plants are:

- reactor protection: the safety and operating systems use common components and need to be separated, insufficient separation of redundancies, low reliability of individual components, deficient local protection system (dangerous rods) and a lack of diverse parameters for initiating important protective actions;
- reactor scram: there is no secondary shutdown system and loss of water in the rod cooling system leads to an high reactivity insertion; moreover in the case of Chornobyl Unit 2, there is a low subcriticality reserve;

- emergency cooling: the low capacity of this function and the partial lack of separation of the emergency core cooling system of the first generation must be highlighted. In the case of the second generation, the emergency cooling is satisfactory (3 x 50 %) but the redundancy separation is insufficient;
- emergency feedwater: it is not designed as a safety system;
- confinement: the primary system consists of a large number of pipes (5000) flanged joints (3000) and valves (2000). There is no containment in the first generation and only a partial pressure confinement system with depressurisation system in the second generation; and
- protection against internal hazards: the fire protection is insufficient.

Even though some important modifications have been implemented at Chornobyl Unit 3, all the strictly necessary improvements have not yet been fully implemented, in particular in the field of the containment, of the positive reactivity coefficient reduction, and of fire protection. The potential for a severe accident will always exist at Chornobyl and elsewhere with RBMKs, whether feasible upgrading has been done or could be further implemented due to the conjunction of inherent design features such as defence in depth deficiencies (no real containment, intrinsic unstability), presence of hundreds of pressure tubes in the core (leading to the possibility of a steam explosion), and the presence of an enormous volume of graphite around the core, which can burn as long as the core is not covered by inert material.

None of the above characteristics exist for PWRs and VVERs which have a strong leaktight containment, are stable reactors, and physically cannot generate an explosive Chornobyl-type accident. Therefore, the overall safety level of an RBMK can never be equivalent to that of a VVER 1000. If the VVER-1000 plants are upgraded, as proposed for K2 and R4 , then the level of safety will be equivalent to that of recently reapproved Western PWRs of the same vintage (Section 8).

#### 10.2.6.4 Occupational exposure

For 1995 it was reported that the average external radiation dose per worker at the Chornobyl NPP was about 7 mSv [10.9]. Clearly there will be differences between occupational exposure for workers operating in Unit 2 compared with Unit 3 due to the effect of the damaged Unit 4. Average occupational doses are higher than those reported for VVER (Section 5)

#### 10.2.6.5 Radioactive waste management and spent fuel storage

Continued operation of the Chornobyl NPP will lead to the production of additional radioactive waste and requirements for storage or transport of spent fuel. In this respect the problems at the Chornobyl NPP are the same as at any other NPP in Ukraine. Indeed, it has been be argued that, for radioactive waste management, the Chornobyl NPP has some benefits over other Ukrainian NPPs given the ongoing work on the Unit 4 sarcophagus which requires the construction of various systems for handling, processing, storage and disposal of significant quantities of radioactive waste and Ukraine Government plans to establish a national radioactive waste manageemnt centre in the Chornobyl exclusion zone. At the same time, continued operation of Unit 3 has many implications for the final entombment of Unit 4.

Spent fuel from the Chornobyl NPP is transfered to Russia and the relevant waste is returned to Ukraine. The waste issue is the responsibility of the Ministry in charge of fuel reprocessing, and of waste management, including the specific case of Chornobyl. There is no significant difference in this respect between the base case and the proposed project for completion and upgrading of K2/R4.

#### 10.2.6.6 Decommissioning and dismantling

The subject of decommissioning and dismantling of Units 1 to 3 at Chornobyl cannot be separated from plans to deal with the damaged Unit 4. Nevertheless, the considerations that need to be taken into account are essentially the same as for other NPPs in Ukraine. One argument that has been put forward for continued operation of Units 2 and 3 is that it would provide for at least part of the costs of future decommissioning including the costs of dismantling.

#### 10.2.6.7 Socio-economic aspects

The population of the town of Slavutich relies on the Chornobyl NPP and, indeed, is partially administered by the NPP management. Whereas closure of the NPP would still require significant technical skills e.g. for decommissioning and work at Unit 4, it is clear that continued operation of Units 2 and 3 could have significant socio-economic benefits in providing for the long term sustainability of Slavutich. It has been stated [10.9] that Slavutich continues to suffer from its perception as a 'community of the doomed' with high levels of stress amongst its residents. A social and psychological rehabilitation programme has had appreciable results and the birth rate in Slavutich is reported to be the highest in Ukraine while morbidity and mortality indicators are decreasing.

On the other hand, there would also be significant socio-economic benefits for the populations of Netishin close to Khmelnitsky and Kuznetsov near to Rivne as a result of the completion, upgrading and operation of the R4 and K2 plants. The local and regional socio-economic aspects of the proposed project will be further evaluated as part of the proposed EAP (Section 9).

## 10.3 Other alternatives

No detailed analysis has been undertaken of other alternatives to the proposed project for modernisation and completion of K2 and R4. Emphasis has been placed here on the 'base case' option since it is clearly the most relevant in the present context i.e. the completion of K2/R4 to allow closure of the Chornobyl NPP. Other alternatives which might, for example, include refurbishment or construction of new thermal plants, increased energy conservation, construction of a new NPP at an alternative site, repowering of existing NPPs, all have associated potential environmental and, in some cases, radiological implications. Any discussion on such alternatives would need to take into account Ukraine's energy policy and anticipated economic development. Whilst the economy remains in a 'transitional' state and whilst clear options exist for completing projects already underway or for continuing the operation of existing NPPs, a detailed discussion of the environmental impacts of alternatives other than the base case must be considered as premature.

## 10.4 Conclusions

One alternative to the K2/R4 completion project is the continued operation of Chornobyl Units 3 and possibly even restart of Unit 2. There is evidence to indicate that, despite the improvements already implemented in safety aspects and culture, RBMK reactors still have safety shortcomings. The comparison of routine discharges from continuing operation of the Chornobyl NPP highlights the fact that they are approximately one order of magnitude higher than from operating two VVER Units. Accidental discharges from the Chornobyl NPP remain more likely and more important than do those for the proposed VVER Units.

There is no substantial difference between the proposed project and the base case with respect to waste management, transport, storage and disposal as far as these issues are taken into account in a centralized organisation at the Ministerś level. Socio-economic advantages and disadvantages will be evaluated as part of the EAP for the proposed project.

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