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THE CASE FOR COMPLETING THE K2/R4 NUCLEAR PLANTS IN UKRAINE:
a critique of the Stone & Webster report of May 1998

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2A.1 Executive Summary

To close Chernobyl and make the site safe was the purpose of the December 1995 Memorandum of Understanding (MOU) which promised US $ 1.8bn of Western assistance for energy projects in Ukraine. This package was to be allocated on 'least cost' criteria, that is, it would be spent on the projects in the electricity sector that provided the best return on capital. The projects were expected to include completion of two part-built nuclear plants, Khmelnitsky 2 and Rovno 4 (K2/R4) which use the Russian WWER-1000 design. However, in February 1997, the Panel of independent experts commissioned by the European Bank for Reconstruction and Development (EBRD) concluded that "Completing these reactors would not represent the most productive use of US $ 1bn or more of EBRD/EU funds at this time".

The major uncertainties identified by the Panel are still there and other factors have moved against the project since the Panel's report:

- Economic activity and electricity demand show no sign of recovery and little progress has been made with economic reform, including industrial restructuring. Consequently, there is still a considerable surplus of installed generating capacity, and the need for additional plant is a long way off.
- The expected completion cost of K2/R4, now US $ 1.7bn, is much higher than stated previously.
- Only a small fraction of the total value of electricity bills is paid in cash as opposed to barter, and non-payment remains high. As a result, there is an acute cash shortage in the electricity sector, inability to buy sufficient fuel and keep plants in efficient working order, and therefore power cuts.
- The spill-over of the financial crisis in East Asia to Latin America and now Russia is likely to affect Ukraine in at least two ways: firstly, reducing export demand for Ukrainian products and, secondly, increasing global demands upon the funds of the international financial institutions. Even before the Russian crisis of August 1998 there was a gap of US $ 1bn between the funding needed for K2/R4 and that which is provisionally pledged. It is doubtful that this can be bridged with funds from Russia, Ukraine and export credit guarantees from Western countries.
- Providing US $ 1.7bn to complete K2/R4 will tend to 'squeeze out' the much needed funding for other electricity sector projects in Ukraine – notably restoring the bulk of existing fossil fuel plant to efficient working order, implementing energy efficiency measures, and safety upgrades at the eleven WWER nuclear plants which could well improve their operating performance as well as safety.
- Experience with the Temelin and Mochovce nuclear plants, in the Czech and Slovak Republics respectively, illustrates the severe problems in completing nuclear plants of Soviet design. Temelin suggests that the financial risk is greater, the larger the amount of redesign, retrofitting, and modifications which are undertaken. At Mochovce, a much less ambitious approach was taken completing the plant largely to the original design. However, the design of plant used at Mochovce was an earlier one to that used at K2/R4 and the need to make improvements to ensure reliable operation was less clear.
- For all WWER-1000 nuclear plants in Eastern Europe and the Former Soviet Union (FSU), operating performance has seldom been above mediocre. Those in Ukraine achieved average load factors of only 59-65 per cent in the four years 1993-96, although there is evi-

dence of better performance over the past 18 months. Nevertheless, the record so far gives no reason to assume that the existing WWERs in Ukraine or K2/R4 will consistently achieve annual load factors above the 67.5 per cent assumed in the Panel's report in February 1997.

- Completing K2/R4 will make it more difficult to implement the reform and privatisation of the Ukraine electricity supply sector (see section 2A.4.1.2). Reform and privatisation are not only the stated objectives of the EBRD with this project, they are also a condition of the International Monetary Fund's Extended Fund Facility to Ukraine approved in September 1998, which is a crucial element in attempts to stabilise the Ukraine economy.

As to the Stone & Webster (S&W) report to the EBRD, a report commissioned by the EBRD to replace the Panel's due diligence study, our conclusions fall under three headings:

2A.1.1 The total reliance on computer modelling

The complete reliance of the S&W report upon computer modelling is unsound (see section 2A.3.1.1). This is chiefly because the computer modelling cannot cope with the pervasive uncertainty that exists in Ukraine. There are two main areas of great uncertainty as far as the K2/R4 project is concerned and they relate to key variables in the model. In the S&W report it is assumed that the actual values of these key model variables will lie within a specified range. Since the effects of these uncertainties are unpredictable, this is extremely arbitrary. To this extent, the conclusion that K2/R4 is 'least cost' is therefore based on guesswork.

There are at least two further problems. Firstly, the computed 'least cost' solution can switch dramatically in response to even small changes in key variable assumptions (especially the assumed generating cost of fossil fuel plant relative to that of nuclear plant). The sensitivity of the modelling results to variations in some of the most uncertain variables was not tested and the risks of the project were therefore not fully identified. Secondly, this type of modelling was developed for centrally controlled investment planning. The international financial institutions are seeking to move Ukraine towards a competitive electric power market in which investment decisions are taken by individual companies on the basis of expected future profitability to the companies themselves. Investment behaviour in competitive markets differs from that under the monopoly conditions that are compatible with the S&W type of least cost modelling. No privately owned company in the world operating in a competitive electricity market has chosen to complete or construct a nuclear station.

In the circumstances surrounding K2/R4, reliance upon 'least cost' modelling will therefore produce a solution in which there can be little confidence. That is why the Panel in February 1997 advocated a cautious and flexible 'minimum regret' strategy for financing investment in Ukraine's power sector. This is not a matter of academic nicety: real risks with long lasting effects are involved for the Ukrainian people if the wrong investment decision is taken in this particular case, as section 2A.4.1.1. explains. The need for investment to be 'least cost', as required under the EBRD's operating principles, is sound. But this does not necessitate total reliance on computer modelling. In our view, the irreducible uncertainties still make a 'minimum regret' strategy far more appropriate.

2A.1.2 The most uncertain variables

The conclusions in the S&W report stem directly from the assumptions fed into the model. Therefore the assumptions need to be examined carefully. The most suspect assumptions are those for variables for which past experience gives little guidance and which are shrouded in great uncertainty so that any prediction of their future values is little more than guesswork.

Two key variables are in this category: the future levels of electricity demand and of fossil fuel prices. Because the uncertainties are so great, the assumptions used by S&W for these variables are no more or less plausible than many other assumptions which could have been used.

We think that S&W's electricity demand projections are near the top of a range of possibilities and that the outcome will be probably be considerably lower Sustained economic growth will probably involve significant reduction and modernisation of Ukraine's traditional heavy industries and the growth of new industries and services; and it should also mark the end of the non-payment of electricity bills. Both factors should strongly encourage more economical use of electricity and other fuels, and they should also promote energy efficiency schemes of the type now being encouraged by the World Bank and the EBRD – though not reflected in the S&W report.

In the case of fossil fuels for power generation, there is no reason to expect their prices to rise in the future and the S&W report follows the Panel in assuming that fossil fuel prices will remain constant in real terms. However, its treatment of coal, especially Ukrainian coal is more questionable. If the coal industry rationalisation plan is reasonably successful, the cost of Ukrainian coal should stabilise or even fall. If it is not successful, coal imports will be available from many low-cost producers, and it is illogical to think that privatised generators in Ukraine's competitive wholesale power market will resist the opportunity to reduce the main element in the cost of coal-fired generation. In any case, the quality of coal which is burned at power stations is as important as the price (see below).

2A.1.3 Other assumptions

Assumptions are used for other variables which are questionable and tend to bias the model results in favour of K2/R4:

- The assumption that certain fossil fuel plants are retired on their 40th birthday is not only arbitrary but it makes the model bring forward by several years the time when new capacity appears to be needed. Dropping this arbitrary assumption delays the need for new capacity until at least 2010. This has two consequences. Firstly, completing K2/R4 substantially before there is a need for new capacity means that K2/R4 has to be evaluated against only the avoidable cost of existing plant on the system and not against the much tougher criterion of the total costs of new plant. Secondly, given that nuclear power already accounts for 45 per cent of Ukraine's electricity supplies, any new plant which is eventually needed would probably be load-following or peak load plant as opposed to base load nuclear plant.
- Other than 'advice from Kiev', no reasons are given for the assumption that the average load factors of the WWER-1000 nuclear plants will rise to 75 per cent by 2010. Given the mediocre performance so far of all WWER-1000 units in Eastern Europe and the FSU, the lack of proper justification means that this assumption is unfounded. On the record so far, it is difficult to justify an assumed future load factor above 67.5 per cent for these plants. However, if improved operating management combined with certain safety upgrades do produce significantly higher load factors for the existing eleven WWER-1000 units, this will give as much additional nuclear output as completing K2/R4. It will also reduce the scope for further inflexible base-load plants. But if the existing WWER-1000 units perform no better than they have so far. K2/R4 are unlikely to do much better than them and is even less likely to be a worthwhile investment.
- Next, we come to the assumption that 200 MW and 300 MW fluidised bed (AFBC) boilers will be retrofitted in 5000 MW of existing coal-fired plants to burn low grade coal wastes, at a cost of US $ 3.4bn. The existing coal-fired plant will remain a mainstay of the power system and the urgent need is, through good maintenance and repair, to enable them to

operate reliably at their design performance. A 5000 MW AFBC programme would be high risk decision given the lack of international commercial operating experience with AFBCs of this size and the unproven nature of the fuel resource expected to be used. There is also the near impossible logistics of building so many AFBCs in such a short period as assumed in the S&W report. Then there are the doubts as to whether the new generating companies will accept the additional debt burden in their accounts, and not least whether the international financial institutions will provide the large loans necessary for such a programme – particularly if they have by then already provided large loans for the completion of K2/R4. Their risk exposure to developments in Ukraine's power sector would be so high as to make lending on such a scale implausible.

- The S&W figures substantially underestimate the thermal efficiency of modern gas fired combined cycle plants (CCGTs) and overestimate their generating costs and pollution emissions. There is every chance that CCGTs would be economically and environmentally the best way of meeting any need for new capacity.
- Close inspection of the S&W figures reveals the implicit assumption that the existing coal-fired plants will continue to burn large volumes of gas, implying that the generating companies will continue to buy such low quality coal that it requires gas in large quantities to make it burn. Yet there is no reason to assume that privatised generators in a competitive wholesale market will put up with poor quality coal and unnecessary gas bills. They can demand good quality control from the Ukrainian coal industry as it is restructured and concentrated on the better mines. If they do not get it, they can get good quality coal at a competitive price from many other countries. And, as the large volume of gas used in coal-fired power generation declines, it will be possible to install CCGTs and incur little additional gas import cost.

The assumptions in the S&W report which result in the conclusion that K2/R4 are 'least cost' are therefore not realistic. They either rest on the pretence of 'knowing the unknowable' or they bias the model towards the desired conclusion. In this, it is like the many previous modelling exercises up to and including the Lahmeyer report which preceded the MOU. Consequently, a decision to finance the completion of K2/R4 on the basis of the S&W report will be a very high risk decision. The EBRD seems to have recognised this in its decision to cut its losses by offering to finance only 11 per cent of the project cost.

It is urgent to find a way to secure the closure of Chernobyl which makes far more productive use of scarce capital resources and brings real benefit for the Ukrainian people. It is they who will bear the costs of the interest bearing loans and the electricity generated and the great safety risk of continuing to operate Chernobyl. The MOU was right in addressing Ukraine's urgent need for capital, but unfortunate in appearing to tie much of the capital to be provided to the completion of K2/R4, a project which is very likely to raise the national electric bill of a country that cannot pay its present bill. Abandoning K2/R4 now would clear the way for a flow of capital to much less risky and expensive projects, of which there are plenty.

2A.2 Introduction

The European Bank for Reconstruction and Development (EBRD) was asked by the G7 to examine whether financing the completion of two 1000 MW nuclear power plants in Ukraine, Khmelnitsky 2 and Rovno 4 (K2/R4 for short), meets sound banking principles and, if so, to arrange the financing. An independent Panel was appointed to carry out the official 'economic due diligence' study on behalf of the EBRD which was published in February 1997.[1] This report assesses the evidence on the case for completing K2/R4 that has accumulated since the Panel's study. It is written by some members of the team which carried out the official 'economic due diligence' but it does not represent the views of that team.

The chief aim is to assess the report by the US consultants, Stone and Webster (S&W), which was submitted to the EBRD in May 1998. This report concluded that K2/R4 is the best use of the available capital, or 'least cost', and, on that basis, the EBRD has given provisional approval for the project to go forward. The first part of this report is a critique of the S&W document. However, the S&W report generally contains little analysis on the key variables. In the second part, we therefore analyse recent developments in Ukraine in areas of key importance to the K2/R4 decision.

2A.2.1 Background to the K2/R4 project

A major aim of the G7 and the European Union since 1992 has been to provide Western financial and technical assistance to improve the safety of civil nuclear power in Eastern Europe and the former Soviet Union (FSU). There are three priorities: first, "to transform the existing Chernobyl sarcophagus into a safe and environmentally stable system", and to secure the permanent closure of the other three nuclear units on the same site; second, to secure the closure of other nuclear plants of the same design as the units at Chernobyl and of WWER reactors of an early Soviet design; and third, to raise the safety standards of other plants of Soviet design to Western levels.

After six years there is little to show for Western efforts. Other plants of the same design as the units at Chernobyl and the early WWER reactors have not been closed, nor, despite some country specific efforts, has a comprehensive programme of safety upgrades of the later series of WWER reactors been undertaken. Some of the Western funds necessary for making the Chernobyl sarcophagus safe are now pledged, but the permanent closure of the remaining units at Chernobyl is still the focus of Western attention.

Since the G7 summit in December 1995 the Ukrainian government has made the closure of Chernobyl conditional upon the provision of Western finance to complete K2/R4.[2] These plants have remained unfinished since 1990 when they were estimated to be 80 per cent complete. The G7 and the European Union (EU) want the EBRD and the Euratom division of the European Commission to finance a large proportion of the cost of completing K2/R4, with national governments (and/or commercial banks) providing the remainder. But the EBRD's own ground rules allow it to finance power sector projects only if they are shown to be 'least cost' (more

[1] Economic Assessment of the Khmelnitsky 2 and Rovno 4 Nuclear Reactors in Ukraine: Report to the European Bank for Reconstruction and Development, the European Commission and the US Agency for International Development by an International Panel of Experts chaired by Professor John Surrey, (2 volumes), SPRU, University of Sussex, England, 4th February 1997. Peter Bradford was a member of the Panel; Gordon MacKerron and Steve Thomas were members of the supporting group which wrote specialist working papers for the Panel. The other members of the Panel were Ferdinando Amman (Italy), David Freeman (USA), Lennart Hjalmarsson (Sweden), and Aviel Verbruggen (Belgium).

[2] However, in 1995 Ukraine proposed a combined cycle gas-fired plant to replace the Chernobyl nuclear plant. The Ukrainian authorities say their proposal was turned down by the West in favour of completing K2/R4, because to build a gas-fired plant would have increased Ukraine's reliance on Russian gas and increased its balance of payments deficit.

economic than alternative projects in the Ukraine electric power sector). There has been a series of attempts to prove K2/R4 to be 'least cost' since 1993, in and outside the public domain.

The Lahmeyer consultants' report, submitted to the EBRD in October 1995 concluded that K2/R4 were indeed 'least cost'. On that basis, the G7 and the Ukraine government signed a Memorandum of Understanding (MOU) in December 1995 whereby the G7 promised that Western finance would be provided for 'least cost' projects. In return, the Ukraine government promised to close Chernobyl by 2000. The MOU pledged around US $ 1.8bn, which was expected to cover not only the completion of K2/R4 but also the rehabilitation of thermal and hydro plants, the completion of a part-built pumped storage scheme and energy efficiency projects. With the level of the completion cost then expected for K2/R4, over US $ 1bn would have been available for non-nuclear projects or for nuclear safety upgrades.

2A.2.2 The Panel's Report of February 1997

Confidence in the Lahmeyer report had evidently waned to such an extent that by mid-1996 the EBRD decided to commission a Panel of independent experts to re-assess whether completing K2/R4 really was 'least cost'. In September 1996 a Panel of US and European experts was appointed by the EBRD with the backing of the US State Department and the European Union, which agreed to meet the costs of the re-assessment. The detailed terms of reference made it clear that the Panel was to carry out the official 'economic due diligence' on behalf of the EBRD and should produce an impartial assessment based on independent expertise and judgement.

In its published report, the Panel stated that:

> *"A frequent flaw running through many of the arguments we have encountered is the tendency to state the unknowable with certainty. Two decision rules should apply strongly: initially decide as little as is needed to further the chosen course of action which increases the public benefit with lowest risk of a high-cost outcome; and thereafter commit resources to the chosen course of action in a measured way, leaving flexibility to respond when, as often happens, events contradict earlier expectations.... When an economy is so dislocated and abnormal (as Ukraine's), and hyper-inflation has wiped out savings, where the international value of the currency is low and many bills remain unpaid, prediction is very difficult .... All the key parameters involved in a 'least cost' assessment for Ukraine are surrounded with great uncertainty".*

This passage set out the Panel's approach to its task. This approach, which is often called 'minimum regret', is relevant for decision-making under conditions of exceptional uncertainty. Such conditions are precisely those in which reliance on 'least cost' computer optimisation is likely to be most risky, since it cannot allow for pervasive uncertainty.

The Panel went on to conclude that K2/R4 are not 'least cost'. Completing these reactors would not represent the most productive use of US $ 1bn or more of EBRD/EU funds at this time. Central to this conclusion were the following points:

- *"Electricity demand has been so reduced by the highly depressed economic situation that there is a large capacity surplus which is likely to last until at least 2010. Installing further surplus generating capacity would use up limited borrowing authority for a purpose not needed and make it more difficult to achieve the efficiency objectives behind the government's market-based reforms throughout the energy sector.*
- *(The Panel has) little confidence in any of the various elements of the estimated costs of completing and operating K2/R4, including waste disposal and decommissioning. This basic lack of confidence in the cost estimates makes K2/R4 a high risk investment – especially as (the Panel has) no reason to think that the avoidable cost of generation from most of the existing fossil fuel plants would be higher than the generating cost of K2/R4 (including the investment cost and an appropriate return on capital).*

- *The need for safety upgrades at the 11 existing WWER-1000 stations is pressing. If the safety upgrades increase reliability, the extra output of the existing nuclear stations would make K2/R4 even more unnecessary. However, if the safety upgrades did not increase output, K2/R4 would be no more reliable than the existing WWERs.*
- *Low energy efficiency in final uses and conversion processes, and high energy losses in electricity transmission and gas pipelines and district heating schemes, present an opportunity to improve overall productivity, reduce energy demand, and increase effective electricity supply capacity – all at relatively low cost."*

The Panel added that

> *"Even if there were need for additional plant in this period (up to 2010), it would be for new or refurbished load following plant, not base load plant. Meanwhile, provided that all consumers resume paying their bills and electricity prices cover full costs on a continuing basis, electric utilities will have the money to buy sufficient fuel and spare parts. When industrial complexes are renovated, the existing 'heat only' district heating plant and high-efficiency cogeneration (CHP) plants will provide power and steam/hot water economically, further reducing the need for new central generating capacity".*

Given the importance of closing Chernobyl, the Panel emphasised that *"there is no shortage of economically attractive projects in the Ukrainian energy sector"* on which US $ 1bn or more could be spent more productively than on completing K2/R4. These included reinforcing the electricity grid where needed; restoring non-nuclear plant to efficient working order; nuclear plant safety upgrades; rehabilitation of municipal district heating plants (including conversions to combined heat and power); and a wide range of energy efficiency projects, especially in infrastructure and publicly owned buildings such as hospitals, schools and pumping plants. The Panel urged that no doubt should be left in Ukrainian minds that the full sum of money pledged in the MOU would be provided if they agree to close Chernobyl.

Stone & Webster (S&W) were immediately hired to re-run the EGEAS model used by the Panel, but with assumptions determined by the interested parties. The S&W report found that K2/R4 were 'least cost'. Nevertheless, this failed to persuade EBRD's top management, who told their international board of directors in June 1997 that K2/R4 could not be proved to be 'least cost' due to the great uncertainties. The directors reportedly instructed the EBRD to "clarify the uncertainties" even though the Panel had emphasised these were great and irreducible. In September 1997, the EBRD hired S&W to re-run the model yet again. After collaboration with EBRD staff and week-long discussions in Kiev with the interested parties and other consultants to decide the assumptions to be used, the model was re-run, and K2/R4 were found to be 'least cost'.

The S&W report was submitted and published in May 1998, and in the following month the EBRD provisionally approved funding of K2/R4 subject to a public consultation process in Ukraine. However, EBRD's provisional funding approval was hedged in ways that would limit its risk exposure on the project and protect its credit rating (see section 2A.4.1.4).

This background illustrates three unusual features of K2/R4 as a major investment project. Firstly, completing K2/R4 appears to be essentially a political objective for which the politicians and officials involved are seeking an economic justification in order to obtain the required funds.[3] Secondly, the way in which the problem has been handled subsequent to the Panel's report no longer remotely resembles an independent, impartial 'economic due diligence' process. Thirdly, the present approach erodes the EBRD's independence as a bank. These features do not bode well for future Western attempts to channel its assistance where it will be most cost-effective or to improve the safety of nuclear power in Eastern Europe and the FSU.

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[3] The political nature of the project stems not only from the wish to close Chernobyl but also from the geopolitical and nuclear industrial interests of the western powers.

2A.3 The Stone and Webster Report

2A.3.1 The Approach and Assumptions

2A.3.1.1 The reliance on 'least cost' modelling

The S&W report relies entirely on 'least cost' power system modelling and the conclusions stem directly from the assumptions fed into the model. By contrast the Panel used modelling only as a supporting tool to provide useful quantification to test the conclusions arising from its own economic analysis and professional judgement. This difference in approach is fundamental and the Panel spelled out why reliance should not be placed exclusively or mainly on that methodology:

- It relies on forecasts of variables which cannot be predicted with any confidence, e.g. the growth of the Ukraine economy, future fossil fuel prices and nuclear generating costs. Moreover, the 'least cost' solution in this type of modelling can switch dramatically in response to even small changes in the assumed relative running costs as between coal-fired plants and nuclear plants.
- 'Least cost' modelling was developed for long-term investment planning in large, centrally controlled power systems. There is a fundamental difference between investment behaviour in centrally planned and competitive markets. Ukraine is moving to a privatised, competitive power market in which investment decisions will be taken not centrally on the basis of minimising overall system costs but by individual companies on the basis of expected future profitability to the companies themselves. It is not difficult to imagine a series of investment decisions being made by the new generating companies which could subsequently mean the owners of K2/R4 would not be able to repay loans without either state support or state subversion of the electricity market reforms that the G7 has worked hard to achieve (see section 2A.4.1.2).
- Unless the key assumptions fed into the model, how they affect the modelling results, and how the uncertainties and risks are dealt with, are all explained very carefully, those who base decisions on the modelling results are liable to do so with insufficient understanding of the risks involved.

In addition, it must be remembered that the EGEAS model treats the Ukraine power system as an 'island' system, with no electricity trade with Russia and other countries. This may be a reasonable assumption at this time of economic dislocation, but it does not reflect the likelihood that full transmission links will be restored in future to allow electricity trade. The scope to import or export power may change the type of new plant required.

Although computer modelling is a useful tool for quantification, it cannot cope at all well with pervasive uncertainty. Instead, it is necessary to assume, as in the S&W report, that the actual values of the key model variables will lie within an assumed range. This was common practice when 'least cost' modelling was used by centrally planned power systems in some OECD countries and vertical integration allowed all cost increases to be passed on automatically to final consumers. Not only is Ukraine moving to a privatised, competitive power market but all parts of its economy face far greater uncertainties than ever faced by the OECD countries.

Given the pervasive nature of the uncertainties, the Panel concluded that uncertainty about the following factors made it impossible to have any confidence that committing large financial resources to the completion of K2/R4 was a 'least cost' approach to the Ukrainian power supply situation:

- The future trends of electricity and energy demand, and the shape of annual electricity demand (or the load duration curve), when economic recovery and industrial re-structuring are under way, when all customers pay for the electricity they use, and when electricity prices are fully in line with costs.

- The extent to which the fossil fuel power plant rehabilitation programme, and the government's plan to concentrate coal production on the lower-cost mines and put the coal industry on a commercial footing, bear fruit.
- The costs of completing K2/R4 including upgrading them where possible to Western safety standards, and of operating them (including the fuel cycle and non-fuel operations and maintenance, waste disposal and decommissioning).

In the circumstances facing Ukraine, reliance on 'least cost' modelling will inevitably produce a solution with a serious risk that it will be wrong. It is therefore important to be aware of the risks involved if K2/R4 prove not to be 'least cost'. If the project goes badly (e.g. there are serious time and cost overruns), the Western institutions involved might not get some or all of their money back and/or the recipients of the loans in Ukraine might not be able to raise further loans in future. But whether things go badly or well for the project, there is still a large risk for the Ukraine power sector. Since the international financial institutions (IFIs) have many claims on their funds apart from the Ukraine power sector, the large sum necessary to complete K2/R4 may make it more difficult to obtain sufficient funds for other projects in the Ukraine electric power sector, especially the task of restoring existing non-nuclear plants to efficient working order. If that were the case, completing K2/R4 would increase Ukraine's nuclear base-load capacity (which already produces 45 per cent of total electricity supplied) while the load following capacity would probably deteriorate further. This would be highly disadvantageous if non base-load demand increases as the economy picks up, and base-load demand falls as Ukraine's traditional heavy industries decline.

The penalty of spending much of the limited capital likely to be available on K2/R4 could therefore be large and long-lasting. Given the nature of the uncertainties, a cautious and flexible 'minimum regret' strategy still seems to be the better approach.

2A.3.1.2 Operating Costs and Performance of K2/R4

The operations and maintenance (O&M) costs and the performance forecast for K2/R4 are two of the most important variables used in the economic appraisal contained in the S&W report. A detailed analysis of trends in operating performance of nuclear power plants is given in section 2A.4.2.1. The operating performance determines how much output there will be over which to spread the fixed costs, primarily construction costs including interest during construction. These fixed costs represent the largest element in the cost of power from nuclear power plants. The operating costs determine what systems savings there will be by operating K2/R4 instead of existing fossil fuel plants which would normally be expected to have higher running costs than nuclear plants. Forecasting nuclear operating costs and operating performance cannot be done with any degree certainty because apparently similar nuclear plants achieve very different levels of performance and costs for reasons that are often not well understood. It is therefore important in the investment appraisal that this uncertainty is fully reflected in any sensitivity analyses.

These two variables, operating cost and operating performance, are interconnected, but the nature of the relationship is not clear cut. Poor reliability is likely to lead to high repair costs, although low-cost maintenance may lead to poor reliability. Equally, good reliability may be achievable only at the expense of heavy maintenance costs.

The variable element of the O&M costs for the existing nuclear plants is almost certain
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and in preference to fossil fuel plants. In all scenarios, the O&M costs for the existing nuclear plants will therefore be a constant in the total cost of supplying electricity regardless of whether K2/R4 are completed. Since the investment appraisal tests the difference between the total cost of supplying electricity with, and without K2/R4, it is not important to forecast precisely the operating costs at the existing nuclear plants.

However, it is important to forecast the load factors for the existing nuclear plants. The higher the load factor for existing plants, the less the system will require the use of expensive, inefficient plant. If K2/R4 are built and the existing nuclear plants perform better than expected, the savings in system operating costs will be less than forecast because K2/R4 will substitute for cheaper than expected plant. In short, the better the existing WWER-1000 plants perform, the poorer the case for K2/R4.

2A.3.1.2.1 Operating Performance

The EGEAS model calculates the load factor from the assumed length of the annual maintenance period, expressed in weeks, and from a forced outage rate, expressed as a percentage of the year when the plant is out of service for reasons other than routine planned maintenance. It should be noted that reductions in break-down time will tend to have greater economic benefits than reductions in maintenance periods This is because maintenance periods are scheduled when system demand is low and relatively cheap-to-run power plants are available to replace the output of the nuclear plants. By their nature, breakdowns could occur when system demand is high and only expensive-to-run plants are available to replace the lost nuclear output. This factor is built into the EGEAS model.

Since nuclear plants are generally operated to produce as much power as they can (i.e., on base-load), the load factor that is used in the EGEAS model can be calculated from the expected maintenance period and the breakdown rate.

One problem with the approach used in the EGEAS model is that it implies that the plant operates at full power all the time it is on-line. As is clear from the data in the detailed analysis of operating performance (see section 2A.4.2.1), this is far from the case (not just in Ukraine). In some years, the WWER-1000s in Ukraine have lost more than 10 per cent of their potential output because they are on-line but not operating at full power (so-called operating losses). This has occurred in Ukraine for a number of reasons, for example, a need to conserve fuel, equipment problems which are not deemed serious enough to warrant full shut-down and the high temperature of the cooling water in summer.

In the period 1993-96, the latest period for which detailed data are available, operating losses for WWER-1000 plants in Ukraine averaged 9 per cent. There is no sign in the S&W report that the possibility of operating losses has been taken into account. If the load factor is estimated simply by examining the average time spent on maintenance per year and the average time spent broken down, the load factors forecast for K2/R4 and the existing WWER-1000s will tend to be over-estimates.

The existing WWER-1000s are assumed in the S&W report to achieve an availability of 67 per cent (it would appear that the term availability is used instead of load factor). This is made up of a nine week scheduled maintenance period and a 15.7 per cent forced outage rate. It is not clear how these figures were derived. They imply a load factor significantly above the 64 per cent average that the Ukrainian WWER-1000s achieved for the five years from 1993-97. More particularly, it is assumed that a programme of performance upgrades costing US $ 78m per unit will bring the 11 existing units up to 75 per cent load factor over a period of ten years. This programme of performance upgrades is said to be entirely separate from the safety upgrade programme being pioneered at the Kozloduy plant in Bulgaria and expected also to be applied to the Ukrainian plants.

No details are given of the changes to be included in the performance upgrade programme and how they will improve performance, e.g., the extent to which maintenance periods are reduced and reliability is improved. Nor is it clear how the performance upgrade programme will be integrated with the safety upgrade programme, especially where they overlap. Given that it is clear from the delays in starting the safety upgrades at Kozloduy (see section 2A.4.2.2), that the ingredients of the safety upgrade programme are still not fully defined after three years of efforts, this new performance upgrade programme must be counted as highly speculative.

In its original report, the Panel assumed a load factor for the existing units of 60 per cent. The good performance since then may mean it is appropriate to raise this forecast to 65 per cent, which will somewhat weaken the economic case for K2/R4. However, if, as has been implied by the Ukrainian safety authorities, some of this improvement has only been achieved by skimping on testing and maintenance, the improvements may be short-lived and 60 per cent may be more appropriate.[4]

For K2/R4, it is assumed in the S&W report that the break-down rate is half that of the existing plants at 7.7 per cent, but the length of maintenance periods is unchanged giving a load factor of 75 per cent. There is no explanation of how these forecasts were arrived at. The Panel in its original report assumed better performance for K2/R4, a load factor of 67.5 per cent, than the existing plants. This was on the basis of the expected improvements in construction, equipment and management that Western involvement would bring to plant reliability. To the extent that the improvement in performance in the past couple of years at the existing plant has been due to the impact of some of these factors beginning to operate, there is not sufficient reason yet for assuming higher performance for K2/R4.

Despite the key importance of operating performance and the serious uncertainties about the level of performance that will be achieved, the S&W report contains no sensitivity tests with different forecasts of load factor. The only relevant test was a simulation in which it was assumed the performance of the existing plants did not improve from 67 per cent to 75 per cent. As argued above, poorer performance of the existing nuclear plants would tend to improve the case for K2/R4, and better performance would tend to worsen it.

2A.3.1.2.2 Operating Costs

The EGEAS model divides operations and maintenance (O&M) costs into fixed costs (expressed as US $/kW per year), variable costs (expressed as US $/MWh) and fuel costs (expressed as US $/GJ). A useful check on the values assumed in the S&W report can be made by comparing these values with the published data supplied by US utilities on their nuclear plants, as a legal requirement, to the Federal authorities and summarised annually in Nucleonics Week.[5] This US data has a number of merits: it is the only independently authenticated set of operating costs available, and it should be accurate and contain no bias; it is up to date, being published within six months of the year to which it refers; and it covers a large sample of plants, 70 stations containing more than 100 units, and is therefore not unduly influenced by specific events at a particular plant. However, in the form published in Nucleonics Week, it does not divide O&M costs into fixed and variable – in practice, this distinction is somewhat arbitrary. US data are divided into maintenance costs and other O&M costs. To compare the US data with the K2/R4 forecasts on an appropriate base, the load factors assumed or achieved must be known in order to determine over how many units of output the fixed costs are spread.

2A.3.1.2.3 Non-Fuel O&M Costs

For K2/R4, the S&W report assumes a load factor of 75 per cent, fixed O&M costs as US $ 30/kW per year, and variable O&M costs as US $ 2.6/MWh. The fixed O&M costs at a 75 per cent load factor equate to US $ 4.5/MWh, giving a total non-fuel O&M cost of US $ 7.1/MWh. If, as is assumed by the Panel, the load factor achieved by K2/R4 was only 67.5 per cent, all else being equal, the fixed O&M costs would increase to US $ 5/MWh and the total US $ 7.6/MWh.

If we compare this with the US data for 1997 (one of the best years in the past decade), the costs assumed for Ukrainian nuclear plants seem extremely low. Only one US plant, which

4 'Ukrainian standards attacked by domestic nuclear regulator', East European Energy Report, July 1998, p 25, Financial Times Energy, London.

5 Nucleonics Week 'The South's efficiency stars make cheapest US nuclear power', June 18, 1998.

achieved a load factor of 96 per cent, was able to beat the figure assumed for K2/R4, while one, which achieved a load factor of 91 per cent, equalled it. The average for all US plants was about US $ 18/MWh, achieved with an average load factor of 71 per cent. This was broken down into about one third maintenance costs and two thirds other O&M costs. As a result of determined efforts in the USA to bring down costs and improve operating performance (this allows fixed maintenance costs to be spread more thinly), this figure has been slowly falling since 1993, when the average was nearly US $ 22/MWh.

Ukrainian and US nuclear power plants are clearly not directly comparable – US labour costs per man hour are likely to be much higher than Ukraine's, but Russian designed plants are much more labour intensive. Nevertheless, an assumption that Ukrainian non-fuel O&M costs will be only 40 per cent of those incurred in the USA requires some justification. The S&W report gives no justification for the figures chosen. Until detailed authenticated costs from WWER-1000 plants are published which clearly show that all costs have been fully documented, it may be more prudent to assume that costs at K2/R4 will be comparable to those of US nuclear power plants. A figure of US $ 20/MWh (higher than the US figure to take account of the impact of the poorer operating performance in Ukraine on the fixed costs) would seem appropriate.

2A.3.1.2.4 Nuclear Fuel Costs

The S&W report assumes fuel costs of US $ 0.56/GJ.[6] Using the assumed heat rate of 11,000 KJ/kWh, this gives a fuel cost per MWh of US $ 6.2. This is very close to the average for all US plants in 1997 of US $ 6.1/MWh, a figure that has been reasonably stable over the past few years. Since there is now an international market for nuclear fuel, for example, Westinghouse is able to supply WWER-1000 fuel, an assumption that costs would be very similar to those in the USA is reasonable.

2A.3.1.2.5 Costs at Fossil Fuel Stations

The costs at fossil fuel stations vary widely according to the technology and fuel used and also to the utilisation. However, to put the running costs of the nuclear plants in perspective and to gain some insight into how changing the O&M costs for K2/R4 will affect their economics, it is useful to get some idea of the indicative costs of fossil fuel stations. In practice, K2/R4 would tend to marginally reduce the utilisation of all stations with a higher running cost so it is not possible to be precise about the impact of completing K2/R4 – that is why a complex computer model is a useful tool in carrying out the investment appraisal.

We can examine the costs of an efficient plant using a cheap fuel assuming base-load operation. According to the S&W data, the Uglegorsk 4 station comprises four units of 300 MW and has a base-load heat rate of 9163 KJ/kWh (39 per cent). It uses a mixture of 85 per cent unwashed coal and 15 per cent gas which in 2005 is projected to cost US $ 1.68/GJ. Its fixed O&M costs are US $ 12.6/kW per year, its variable costs US $ 5.5/MWh and its maximum load factor is about 70 per cent. This gives a non-fuel O&M cost of US $ 7.5/MWh and a fuel cost of US $ 18.6/MWh, to give a total production cost of US $ 26.1/MWh compared to the S&W figure for K2/R4 of US $ 13.3/MWh. If the output of K2/R4 only replaced such efficient plants, the savings in running costs for K2/R4 together would be US $ 168m per year. However, if the running cost of K2/R4 was closer to the figures for US nuclear plants, US $ 26.2/MWh, the savings would be minimal.

Despite the crucial importance of the forecast of O&M costs for the projected viability of the project and despite the wide variability in O&M costs found elsewhere in the world, even for apparently similar plants, no sensitivity tests on the O&M costs were reported in the S&W report.

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6 In fact the S&W report does not specify the fuel cost for K2/R4, but it is assumed that the fuel cost will be the same as that assumed for the other WWER-1000 plants.

2A.3.1.2.6 Conclusions

On the above evidence, the operating performance of K2/R4 has been significantly over-estimated and their running costs seriously underestimated. The S&W report assumes the load factor for K2/R4 will be 75 per cent, well above the level any of the operating WWER-1000 plants in service in the FSU and Eastern Europe has achieved. Such a level of performance may be a useful target but is entirely inappropriate for investment appraisal which should be based on the most likely outcome. The lack of any sensitivity tests of operating performance for K2/R4 suggests an assumption that performance levels are highly predictable. This is far from the case: nuclear operating performance varies widely from plant to plant even for apparently similar plants.

The S&W report assumes a total production cost (including non-fuel O&M and fuel) of about US $ 13/MWh. Official US data for American plants suggests that an assumption of double that, US $ 26/MWh, would be more appropriate. The likely savings in operating the Ukraine electricity supply system are highly sensitive to the running costs of the nuclear power plant. For example, using S&W data, K2/R4 will operate at half the cost of a cheap, efficient fossil-fired plant, while basing the costs on US experience, the savings disappear. Again, the lack of any sensitivity testing on the O&M costs is a serious omission. In the USA, O&M costs vary by a factor of three or more with no obvious explanatory factors.

2A.3.1.3 Assumptions on Existing Fossil Fuel Plant and New Capacity Options[7]

The assumptions made on existing fossil fuel plant and on new capacity options in the S&W report are of key importance to the economics of K2/R4. The main assumptions include:

- the production costs of existing fossil fuel plant (fuel and non-fuel operations and maintenance (O&M));
- the cost of rehabilitating and upgrading existing fossil-fuel plants, and their production costs after rehabilitation;
- the costs of new capacity alternatives to K2/R4, including combined cycle plant, open cycle gas turbines and the part-built Dniester pumped storage plant;
- the rate of retirement of existing fossil-fuel plants.

Before discussing these options, it is useful briefly to discuss the circumstances in which investment in new generating capacity can be justified.

2A.3.1.3.1 The case for new plants to reduce system cost

As long as Ukraine has more than sufficient capacity to meet electricity demand, the important factors in assessing K2/R4 are the production costs of existing plants and the costs of rehabilitation. K2/R4 will be economic if the sum of the fixed costs resulting from the completion of these plants and their subsequent operating costs is less than the cost of operating (and rehabilitating where necessary) the plants K2/R4 would effectively replace (in short, systems cost savings). The fuel costs assumed by S&W are examined in section 2A.3.1.4. It has not been possible for us to check the non-fuel O&M costs contained in S&W report, as this would require detailed information for each plant. The production costs of existing plants which are not rehabilitated are therefore not discussed further in this section.

The total cost of operating existing plants will be affected by any major rehabilitation and upgrade projects which reduce their operating costs. Of particular relevance is the option to replace conventional boilers at existing coal-fired power plants with atmospheric fluidised bed combustion (AFBC) boilers, such as the ongoing upgrading of one of the units at the Starobeshevo coal-fired plant (unit 4, 210 MW). The S&W report suggests that 20 such upgrades

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[7] We are grateful to Jim Watson of SPRU for a very significant contribution to this section.

(5000 MW of capacity), half at 200 MW and half at 300 MW units, completed by 2005 would be economic. Less radical rehabilitation options are considered in the S&W report, but since they do not change the essential economic characteristics much and do not feature much in the 'least cost' plans, they are not discussed further.[8] Energy efficiency improvements which reduce demand will also tend to weaken the case for K2/R4 on systems cost savings grounds as they will tend to reduce the usage of the most expensive plant and will mean that the plant that K2/R4 would substitute for will have lower costs (and hence lower potential cost savings for K2/R4) than if the energy efficiency measures were not undertaken. Energy efficiency improvements are discussed in more detail in section 2A.3.2.1.

2A.3.1.3.2 The case for new plant to meet capacity need

The calculations become very different when new capacity is needed in order to meet demand in full. In this situation, the relevant comparison for K2/R4 will be with other new capacity options. The calculation is not quite as simple as it might appear at first sight. Depending on the characteristics of the existing plants and on the relative costs of base-load and peaking plants, it may be economic to add a base-load plant (typically having high capital costs, but low running costs) or it may be cheaper to build peaking plant (typically having low capital costs, but high running costs). A system simulation model, such as EGEAS, is therefore needed to test what type of plant is required. However, given that EGEAS finds a case for K2/R4, which are base-load plants, some simple, but useful comparisons can be made with other base-load options.

The time when new capacity is required will depend on electricity demand growth rates (examined elsewhere) and also on the rate at which existing plants are retired. To the extent that energy efficiency improvements reduce peak demand and postpone the time when new capacity is needed, they can also be regarded as a new capacity option. Only one new base-load capacity option, combined cycle gas turbine plants (CCGTs), is examined in detail here. Experience elsewhere in the world suggests this is generally much the cheapest option on a cost per kWh basis for new generating capacity.

In section 2A.4.1.1, we argue that as the Ukrainian economy is modernised, the structure of the economy will tend to shift away from electricity-intensive industries, which operate round the clock, to much lower intensity sectors which have a more peaky demand for electricity. In addition, consumption by the residential sector, which also tends to be peaky, may also become a more important element of electricity demand. These changes may mean that peaking plant rather than base-load plant is a more economic way to meet demand growth. The assumptions made by S&W on the open cycle gas turbine are therefore examined briefly here. The case for completing the Dniester pumped storage plant is different again and is briefly discussed later.

2A.3.1.3.3 Rehabilitation with AFBC

The Starobeshevo project represents by far the largest loan so far granted by the EBRD to the Ukrainian electricity supply industry (see section 2A.4.1.4). The programme of AFBC rehabilitation of 20 old coal-fired units (5000 MW) by 2005 foreseen in the S&W report would represent a huge investment requirement of (on S&W figures) US $ 3.4 bn, by itself more than using up all the US $ 1.8 bn of loans promised to Ukraine in the MOU with the G7. Close scrutiny is therefore required as to why the model finds this option so attractive and whether the assumptions made are plausible.

The attraction of this technology is that it can burn difficult but cheap fuels, such as high ash anthracite and coal-mining wastes, with low emissions of sulphur dioxide and oxides of nitrogen. In Ukraine's case, the plant rehabilitated in this way is expected to burn a fuel largely composed of coal-mining waste products (so-called schlamm) of which, more than 180 m ton-

[8] One low-level rehabilitation project at an 800 MW unit is under way and the S&W report finds scope for 2000 MW of further rehabilitation by 2010.

nes is claimed to be immediately available at very low cost. The EGEAS model finds this option attractive because the cost of fuel is so low that even the high cost of AFBC boilers (more than the total cost of a new gas-fired plant on a cost per kW) can be justified.

Plant rehabilitated in this way is assumed to be essentially new, with an additional life-time of 25 years. The assumption that this plant is rehabilitated and has a long operating life after rehabilitation has an important impact on the output of the model. If rehabilitation was not assumed and similar assumptions on this old plant's lifetime were made as for other old fossil fuel plants (see below), it is likely that much of this plant would have been expected to be retired by 2010. This would have created a need for a considerable volume of new capacity, probably a large number of new CCGTs, or possibly completion of the other part-built nuclear plants at Khmelnitsky and South Ukraine. If the CCGT option had been chosen, the increased consumption of natural gas implied might have raised major concerns about dependence on Russian gas, as it did when the CCGT option was proposed by the Ukraine authorities in 1995. As argued below, the S&W approach on plant lifetimes is totally inappropriate, but this does illustrate the need to scrutinise carefully all assumptions going into a model like EGEAS.

2A.3.1.3.4 Technological Aspects of AFBCs

International operating experience of AFBC boilers in the 200-300MW size range is extremely limited. The variant of AFBC technology which is normally used for larger installations is known as the Circulating Fluidised Bed (CFB). At present, there are only a few units which have capacities of 200 MW or larger: one has only been in operation since 1995 and the remainder are under construction or recently ordered:

- The first plant of this size, a 250 MW Fluidised Bed at Gardanne in France, went into operation in 1995. The plant uses Lurgi technology and was constructed by Alstom Stein Industrie.
- Two 235 MW units are being re-powered with CFB boilers at the Turow power plant in Poland. They are due to be commissioned during 1998. A third 235 MW unit has been ordered. The boilers were supplied by Foster Wheeler.
- Two 220 MW units are being constructed at the Tonghae power plant in South Korea by ABB Combustion Engineering.

S&W state that the first of the Ukrainian AFBC boilers, a 210 MW unit for the Starobeshevo Power Station, is now being installed with EBRD financing. Whilst the approval of finance for this initial project has been confirmed by the EBRD,[9] we have found no evidence that an order has been placed with one of the equipment manufacturers.

Two designs of CFB dominate the world market. The first, by Foster Wheeler of the USA, was acquired through a take-over of the Finnish firm Ahlstrom. The second, by Lurgi of Germany, has been licensed to many manufacturers including Alstom Stein Industrie of France and ABB Combustion Engineering of the USA. However, it is probable that the equipment supplier for Starobeshevo will be US Babcock and Wilcox, a company that has carried out some combustion tests with Ukrainian anthracite (higher quality fuel than schlamm) with funding from the US Department of Energy. It has also licensed its AFBC technology to a Ukrainian company, Kotloprominvest.[10] Unlike the market leaders (Foster Wheeler, ABB Combustion Engineering and Alstom Stein Industrie), Babcock and Wilcox do not have a track record in the larger 'utility-scale' size ranges.

A further uncertainty for the Ukrainian AFBC programme stems from the plan to use coal-mining wastes. Similar fuels have been burned in fluidised beds for a number of years in the USA. However, as with AFBC technology in general, there has been little or no experience of

[9] ‘Ukraine’s Starobeshevo Power Plant Modernises with EBRD Financing’, EBRD Press Release, (17th December 1996).

[10] F Belin et al, ‘Re-powering of Ukrainian Power Plants with CFB Boilers’, Babcock and Wilcox, Technical Paper BR-1605, (December 1995).

the use of this fuel on a comparable scale to that proposed for Ukraine. Furthermore, there is a serious risk that Ukraine's stocks of this fuel would be insufficient to supply 5000 MW of AFBCs throughout their lifetime. The limited availability of similar fuels has been identified as a major reason for the end of the USA's AFBC boom of the mid-1980s.

2A.3.1.3.5 The Economic Case for AFBCs

The capital costs of the Starobeshevo project have been given as US $ 163m (or US $ 780/kW) at December 1996 prices. This figure is higher than the US $ 655-695/kW range which is used in the S&W model. However, it is broadly in line with the costs of the Polish Turow rehabilitation project: US $ 783/kW for the first 470 MW phase in June 1995, and US $ 836/kW for the second 235 MW phase in September 1997.[11]

Some variation in the costs of such rehabilitation projects is to be expected since the scope of the 're-powering' work will vary between one plant and another. However, the limited evidence suggests that S&W's assumed capital costs which have been used in the 'least cost' model are 20 per cent or more below recent comparable orders.

The S&W report assumes Starobeshevo 4, expected to return to service in 2000, will burn a mixture of 85 per cent schlamm and 15 per cent unwashed coal (so-called schtib). This is assumed to cost US $ 0.74/GJ, a cost which remains constant in real terms throughout the forecast period and will be burned at a heat rate of 9875 kJ/kWh (about 36 per cent). This gives a fuel cost per MWh of US $ 7.4/MWh, only a little more than the projected cost of nuclear fuel (US $ 6.2/MWh) and only about 40 per cent of the fuel cost of an efficient coal-fired plant.

Operated at base-load, the plants are assumed to be capable of a load factor of 81.5 per cent. For the 200 MW plants, the variable O&M costs are US $ 6.5/MWh and the fixed costs are US $ 17/kW per year. This gives a total non-fuel O&M cost of US $ 8.9/MWh and a total production cost of about US $ 16.4/MWh. For the 300 MW plants, the fixed O&M costs are US $ 14/kW per year, the variable O&M costs are the same as for the smaller units and the total non-fuel O&M costs are US $ 8.4/MWh, giving a production cost US $ 15.8/MWh. This compares with S&W's projections that the WWER-1000s would cost about US $ 13.3/MWh and the cheapest conventional fossil fuel plants US $ 27/MWh. The low cost and the high quantities of schlamm are therefore crucial to the economic case for converting 20 further units after Starobeshevo.

The Starobeshevo project may be a useful way to test AFBC technology in Ukrainian conditions to establish its cost and technical viability. It will also test the costs and availability of the schlamm expected to be burnt. If all goes to plan, Starobeshevo will be completed by the end of 2000. If no operating experience is acquired before ordering of the 5000 MW anticipated in the S&W report begins, assuming a construction time of two years, this would require loans of more than US $ 3bn to be raised in only three years. It would also place heavy demands on the Ukrainian plant owners to manage simultaneously up to 20 complex site-based construction projects, each of which will have its own characteristics based on how much rehabilitation is required to the non-boiler part of the plant.

Since the boiler has yet to be ordered, the completion of Starobeshevo may be delayed by a year or more. If operating experience with this fuel and technology is to be gained before series ordering begins, the timetable for the 5000 MW programme would become hopelessly tight and slippage would occur. All this assumes that an international funding package of the size necessary to build 5000 MW of AFBCs in Ukraine could be assembled at the same time as funds were being raised for Rovno 4. Given current and prospective pressures on the principal IFIs, this seems very much in doubt even if the Ukrainian generating companies were willing and able to accept this level of debt.

[11] 'Foster Wheeler Contract for Upgrade of Polish Power Station is Model for Future Eastern European Power Development', Foster Wheeler News Release, (15th September 1997).

2A.3.1.3.6 Combined Cycle Gas-Fired Plants

The S&W report includes as a possible alternative to completing K2/R4 building new power plants based on Combined Cycle Gas Turbine (CCGT) technology. The CCGT has become an increasingly popular technology in many countries during the past 15 years. The CCGT comprises one or more gas turbines, accompanying waste heat boilers and a steam turbine. Electricity is generated in the gas turbine and the hot waste gases from this are passed through a waste heat boiler where steam is generated. This steam is used to drive a steam turbine where more electricity is generated. This produces a much higher thermal efficiency than is possible with just a gas turbine (open cycle) or a conventional steam turbine.

There are now over 200GW of CCGTs in operation or under construction throughout the world. In terms of its commercial status, the CCGT is therefore a well proven commercial technology. A particular advantage of CCGTs, which may be relevant to Ukrainian conditions is that, unlike AFBCs and nuclear plants, they are largely factory produced and require little site-work. This is regarded as a major advantage in the West because problems in managing sites at complex civil engineering projects have often led to escalation of construction costs and delays to completion of projects. The performance of CCGTs is also much more predictable, with the suppliers willing to offer much stronger performance guarantees than would be possible for nuclear or AFBC plants.

A key feature of the CCGT is the speed at which technical progress is being made. Since the late 1980s, typical thermal efficiencies have risen from 46-48 per cent to the current level of 56-58 per cent. This performance improvement has been made possible almost exclusively by technical progress with gas turbines. The fierce competition which characterises the international CCGT market has also exerted heavy downward pressure on capital costs. It would appear that the data used in the S&W model does not take account of these trends. The data appears to be about ten years out of date. To illustrate this point, Table 2A.1 makes a comparison between the S&W CCGT and two recent CCGT projects in the UK.

Table 2A.1: The Economics of CCGTs

Year	S&W 1998	Didcot B Ordered 1994	Rocksavage Ordered 1996
Output (MW)	300.00	1350.00	720.00
Thermal Efficiency (%)	47.60	56.00	58.00
Capital cost ($/kW)	750.00	475.00	500.00
Capital cost ($/MWh)	16.20	10.20	10.50
Fuel cost ($/GJ)	2.65	2.70	2.70
Fuel cost ($/MWh)	20.10	17.60	15.10
Fixed O&M Cost ($/MWh)	0.90		
Variable O&M Cost ($/MWh)	3.00	4.00	4.00
Total ($/MWh)	40.20	31.80	29.60

Source for UK figures: SPRU CCGT database; publications by project developers and manufacturers.

Notes: 1. Calculations for all plants assume a load factor of 85 % and a discount rate of 10 %.
2. Capital costs are overnight costs – they do not include interest in construction.
3. The data available for the two UK projects do not divide non-fuel O&M costs into fixed and variable.

Table 2A.1 shows two major discrepancies between the UK CCGT projects and the figures that have been used by S&W. The first of these centres on the capital cost figure used by S&W. Their capital cost of US $ 750/kW, which does not include interest charged during construction, is significantly higher than the costs of recent CCGT plants. In the UK, a capital cost figure of US $ 500/kW is common (this was the cost of both the Didcot B and Rocksavage

CCGTs). A similar figure is often quoted for CCGTs constructed in the USA. If a Ukrainian CCGT was procured using a competitive process – allowing the major international companies such as GE, ABB and Siemens to bid against each other – US $ 750/kW would be a very poor deal indeed.

The second discrepancy between S&W's assumptions and actual experience relates to the thermal efficiency of CCGTs. S&W have assumed a figure of 7570 kJ/kWh (47.6 per cent). If their calculation was being carried out in 1988 rather than 1998, this figure would be accurate. However, during the last decade, rapid technical change has pushed thermal efficiencies past 55 per cent. Many CCGTs that are now under construction are designed to operate with efficiencies of 57-58 per cent. The UK experience (and that of many other industrialised countries) shows that these projections can be realised.

It may be that S&W assume that a Ukrainian power company would not wish to order a 'state-of-the-art' CCGT, although this hardly fits in with their policy towards AFBCs. The series of reliability problems that have affected the more advanced CCGT designs during the past two or three years have led to increased caution amongst developers, bankers and insurers. Nevertheless, a conservative approach, which uses an older tried and tested CCGT design (plants of the Didcot and Rocksavage technology 'vintage' are already in service and are no longer untested), should still assume a minimum efficiency of at least 55 per cent.

Without running the EGEAS model with different assumptions, it is not possible to know the impact of using more realistic CCGT data, but some strong pointers can be derived. Using S&W's assumptions, the operating cost (including fuel) of K2/R4 would be US $ 13.3/MWh and the operating cost of a CCGT would be US $ 24/MWh. The construction cost of K2 and/or R4 would be in the range US $ 500-700/kW (depending on factors such as the timing and whether both plants were completed), compared to US $ 750/kW for CCGTs. Given that, using these assumptions, K2/R4 are both cheaper to build and to operate than CCGTs, it is clear that EGEAS will choose to complete K2/R4 before building CCGTs.

However, it was argued earlier that, if authenticated US data are a good guide to nuclear O&M costs, the operating cost of K2/R4 will be closer to a figure of US $ 26/MWh. On well-documented international evidence, a more realistic assumption for the construction costs of a CCGT would be US $ 500/kW. Using these assumptions, CCGT capacity would be cheaper to build and operate than K2/R4. Given the uncertainties about the condition of K2/R4 and the extent of any safety upgrades necessary, the CCGT, which is largely factory-built and which has a long record of international experience with comparable plants, would appear to be a much lower risk option than K2/R4 which will mainly require site work.

2A.3.1.3.7 Rate of Retirement of Existing Fossil-Fired Plants

The S&W report states that the retirement dates of the existing fossil-fuel plants were supplied by the Ministry of Energy and Electrification in Kiev. The total capacity of plant retired by 2004 (the figures are not made explicit) appears to be about 6000 MW, mostly apparently on their 40th birthday (no further pre-determined retirements after 2004 are imposed). These pre-determined plant retirements are a major contributor to the need for new capacity identified in the S&W report from 2007 onwards. In S&W's three electricity demand forecasts, this amount of plant is more than equivalent to the growth in peak system demand between 2007 and 2010. If they were not imposed, there would be no need for new plant before 2010 in either the S&W central or low electricity demand case.

Any pre-determined retirement programme, based simply on retiring plants at a given age, is entirely inappropriate. Fossil-fired plants contain no life-limiting components and, in principle, can be operated indefinitely. Retirements should occur only on two grounds: first, when there is no prospect over the following years that the plant will be required; or second, when the cost of constructing and operating a new replacement plant is less than the cost of operating the old plant. A plant retirement schedule should therefore be a model output, not an input assumption: making it an input assumption biases the model towards the addition of new capacity. In reality, given the ongoing privatisation of the electricity supply industry in Ukraine, decisions on retirements will not be taken by government departments, but by commercial companies on the grounds outlined above.

All electricity supply systems need plants which are required only for a few hours a year to meet peak loads. Existing plant with very high running costs might well be the cheapest way to meet this need, so high running cost alone is not a justification for retiring a plant.

In Ukraine's current situation of huge plant over-capacity, but very poor state of repair of the fossil-fuel generating stock, high priority should be to begin a progressive programme of enhanced maintenance to bring the stock of power stations up to a reasonable standard of repair. Only plants which would require prohibitively high costs to bring them back to a reasonable state of repair should be retired. Whether or not K2/R4 are completed, the existing stock of plants will remain the mainstay of the Ukrainian system for a decade or more to come. Such a programme is therefore essential if the Ukrainian electricity supply system is to function reliably.

2A.3.1.3.8 Conclusions

Investment in new generating capacity can be justified either when the addition of new capacity to replace existing capacity will reduce the total system cost of generating electricity (systems cost savings) or when additional capacity is needed to meet demand (capacity need). The former condition is much more difficult to satisfy as it requires that the cost of building and operating the new plant should be cheaper than operating existing plant. In a situation of capacity need, provided it is known whether base-load or peaking capacity is required, the option which is the cheapest on a cost per kWh basis should be chosen. Investments to achieve systems cost savings are optional and, in the case of a country like Ukraine which has a serious shortage of investment capital and heavy foreign debts, are unlikely to be a high priority. Using the S&W assumptions, the systems cost savings criterion will apply until 2007, after which the capacity need argument would apply.

Close examination of the data used in the S&W report suggests that there are serious deficiencies with the assumptions made for all the major fossil fuel options. Firstly, the assumption that a significant capacity of existing fossil fuel plant is retired by 2004 is crucial in creating an apparent need for new capacity from 2007 onwards. However, imposing a pre-determined retirement date for existing fossil fuel plant is not the appropriate way to deal with old plant. The correct way to deal with it would be to estimate the costs that would be incurred in keeping this plant in service and then allow the model to calculate whether it is economic for it to be retired and replaced by new plant. The EGEAS model is perfectly capable of doing this.

Secondly, the existence of large quantities of burnable coal wastes and AFBC technology to burn it opens up the possibility that existing fossil-fired plants could be economically converted to burn it. However, until Starobeshevo is complete, operating reliably and its costs known, and until the viability and cost of delivering schlamm to power stations are established, it is too early to judge whether it would be cost-effective to launch a programme of 20 (5000 MW) AFBC conversions to be complete by 2005, as envisaged in the S&W report. It is not only probably logistically impossible, but it is doubtful that the privatised generators could accept the debt burden involved.

Thirdly, the way in which the main competitor to K2/R4 (if new capacity is needed), the CCGT, is treated is in stark contrast to the treatment of AFBCs where a relatively unproven technology and fuel are rapidly deployed in large volumes. The figures used for the CCGT appear to be about ten years out of date (and the same is true for the main option if new peaking capacity is required, the OCGT). More realistic cost data for CCGTs suggest that this option is likely to be a much cheaper way of meeting any need for base-load generating plant. Moreover, provided they have suitably flexible gas contracts, CCGTs are much better suited to non-base load operation than nuclear plants. CCGTs are also likely to have far fewer economic risks because much stronger guarantees on performance and costs are available from the equipment suppliers.

On all except the S&W high demand growth scenario, there is no need for K2/R4's 2000 MW of capacity until after 2010, by which time any capacity need may be for load-following, as opposed to base-load plant.

OTHER OPTIONS

Open Cycle Gas Turbines

If peaking rather than base-load capacity is required, the most likely option is open cycle gas turbines (OCGTs). The economics of open cycle gas turbines are not discussed in detail here, but the assumptions fed into the EGEAS model on OCGTs suffer from the same problems as CCGTs. The capital cost of an OCGT is assumed by S&W to be US $ 375/kW and the thermal efficiency 11097 kJ/kWh (32 per cent). More realistic figures based on international experience and modern technology would be US $ 250/kW and 36 per cent thermal efficiency. Whether these more attractive figures, and the more peaky electricity demand profile Ukraine is likely to move to are sufficient to make OCGTs more attractive than CCGTs when new capacity is required would need special runs of the EGEAS model.

Pumped Storage Capacity

Pumped storage plant uses electricity generated at times of low demand in low cost plant which would not then otherwise be used, to pump water using a turbine from a low to a high reservoir. When demand is high, the turbine is reversed and electricity is generated by allowing the water in the high reservoir to fall back to the low reservoir. About 30 per cent of the power used for pumping is lost in this process. Pumped storage capacity serves a number of functions: it has a very fast response time and can be used when demand increases rapidly or a plant breaks down to provide power to the system in a matter of seconds; it can also reduce the usage of expensive to run plant by effectively substituting it with cheaper plant.

Whether the completion of Dniester is economic will depend on whether there is a need for additional rapid response plant and on the cost difference between the plant which would be available to pump water at low demand periods and the plant that would be substituted by Dniester at peak times (systems cost savings). This has to be large enough to more than compensate for the 30 per cent of power lost in pumping. While EGEAS is able to estimate any systems cost savings, it is not well suited to checking the need for fast response plant.

It should be noted that the case for rapid response plant is likely to be highly dependent on whether it is assumed that the Ukrainian system is connected to the Russian system. If Ukraine is connected to the much larger Russian system, with its large quantity of flexible hydro-electric plant, the need to cope with rapid requirements for power would be handled without difficulty. This re-emphasises the need to improve the reliability of the Ukrainian electricity system so that Russia is prepared to synchronise its system to that of Ukraine. Using a system simulation model, the Lahmeyer report found a strong case for completing Dniester, while the S&W report and the Panel's found no case for completing it.

2A.3.1.4 Future electricity demand

Future levels of electricity demand are very difficult to predict for Ukraine. Forecasts produced by the international financial institutes of the economic performance of Ukraine, and hence its electricity demand, have consistently been too optimistic and have subsequently had to be revised downwards.

The current economic crisis in Russia, the major export market for Ukrainian goods, has begun to have a serious recessionary effect on Ukraine from the second quarter of 1998 onwards. This will have a significant impact on electricity demand as many of Ukraine's exports to Russia are basic materials, such as steel and chemicals, whose manufacture requires large amounts of electricity. This effect will be reinforced as the financial and banking crisis in Russia spills over to Ukraine. It could be further exacerbated if the conditions of the International Monetary Fund's (IMF) recently negotiated Extended Fund Facility, EFF, (see section 2A.4.1.4 for a discussion of the IMF loan), aimed at preventing the further collapse of the Ukraine economy, are not met and the EFF is withdrawn. The S&W assumptions on economic performance and electricity demand, based on projections made in mid-1997, could take no account of these recent developments.

The S&W report has three electricity demand scenarios, 'Low', 'Middle' and 'High'. In the 'High' scenario, demand grows from 1998 onwards and, from 2000 to 2010, peak demand increases by 50 per cent (4 per cent per year) to 45.8GW. In the 'Middle' scenario, demand falls a little further, beginning to grow in 2000 and from 2003 to 2010, grows at an average of about 3.9 per cent to 39.3GW. In the 'Low' scenario, demand falls by a further 9 per cent by 2001, then grows rapidly (an average of 5 per cent) to 2010, when peak demand is 40.1GW.

The apparent sophistication and detail contained in these forecasts, with demand growth rates expressed to two places of decimals, is hard to reconcile with the extreme uncertainty on future electricity demands in Ukraine. In addition, in many respects, the scenarios do not represent a wide range of possibilities: the main difference between them is the extent to which demand falls from 1997 levels and when demand begins to pick up again. Once demand growth has resumed, in all cases it is a continuous 4-5 per cent. System load factor, a measure of the 'peakiness' of demand, which might be expected to fall the more the economy moves away from heavy industries, is the same for all scenarios. The three scenarios are therefore far from an adequate representation of the range of possibilities.

In the Panel's 'Central' scenario, peak demand in 2010 was forecast to be 37.5GW. The Panel found difficulty in envisaging circumstances in which electricity demand would grow rapidly. This was because economic recovery seemed plausible only if the economy is restructured away from reliance on the old, electricity-intensive industries, which cannot compete on the world market. New industries with the scope to grow rapidly will tend to be in much less electricity-intensive sectors and will be competitive only if they are efficient, including in their use of electricity.

The spill-over of the economic crisis from Russia and the lack of political consensus in Ukraine on the measures necessary to revitalise the economy mean that economic recovery appears no closer than when the Panel's report was written, nearly two years ago. The Panel's 'Central' scenario is therefore now likely to be too high. Given that more than 55GW of plant is in service now, the need for new plant is even further away, beyond 2010.

We think that S&W's electricity demand projections are near the top of a range of possibilities and that the outcome will be probably be considerably lower Sustained economic growth will probably involve significant reduction and modernisation of Ukraine's traditional heavy industries, and the growth of new industries and services. Both factors should strongly encourage more economical use of electricity and other fuels, and they should also promote energy efficiency schemes of the type now being encouraged by the World Bank and the EBRD, though not reflected in the S&W report.

2A.3.1.5 Decommissioning Costs

Estimates of the cost of decommissioning K2/R4 are inevitably subject to a wide-range of uncertainty because no commercial-scale nuclear power plant has been decommissioned fully anywhere in the world. A common way of presenting the decommissioning cost is as a percentage of the cost of construction. However, this is merely a way of expressing the cost, not a way of estimating it. There is no logical reason why an increase or decrease in the construction cost of nuclear plants should inevitably lead to a proportional change in the cost of decommissioning.

The S&W report uses this presentational device, assuming decommissioning costs will be 15 per cent of what K2/R4 would be estimated to have cost had they been built without interruption or design changes. Using this hypothetical construction cost of US $ 2750 per kW, the decommissioning cost is assumed to be US $ 412.5 per kW for the cost based on EnergoAtom's completion cost estimate, the S&W 'low' case. The S&W 'central' completion cost case is 20 per cent higher, making the decommissioning cost US $ 495 per kW and the 'upper limit' completion cost is 28 per cent higher again, making the decommissioning cost US $ 634 per kW. While it is desirable that the uncertainty about decommissioning cost should be fully reflected by examining a range of decommissioning costs in the sensitivity tests, this assumed correlation between construction and decommissioning costs is not logical.

A further, and serious problem with the decommissioning cost estimates is that they take no account of actual experience in the USA. While no large US nuclear power plant has been fully decommissioned, a number of large plants have been retired recently and contracts have been signed for decommissioning based on detailed surveys of the work required. These would seem to offer a better basis for estimates than the mechanical use of a percentage of construction cost (see Table 2A.2).

Each decommissioning operation is highly specific, varying according to the history and design of the plant, the cost and availability of waste disposal facilities and the strategy adopted. Nevertheless, if the figures for US plants are brought up to 1997 money, the average for the three projects for which cost estimates are available is about the same as the central estimate used in the S&W report. Even these relatively soundly based estimates must be treated with some scepticism. There are few examples in the history of nuclear power projects of prior cost estimates proving to be an over-estimate. It would not be surprising if these estimates were to turn out to be too low.

The S&W practice of linking decommissioning cost with completion cost is inappropriate. However, the uncertainty about the cost of decommissioning and about the returns a segregated fund will be able to make over a 30 year period mean that sensitivity analyses should take account of the possibility of considerable variability about this central figure. An upper case 28 per cent higher, US $ 522 m and a lower case 20 per cent lower, US $ 326 m, would be a reasonable range to test.

Table 2A.2: US Nuclear Decommissioning Estimates

Plant	Tech	Size (MW)	Retire Date	Cost $m	Cost $/kW	Estimate Date	Estimate Comments
Maine Yankee	PWR	920	6/97	508	552	11/97	
Rancho Seco	PWR	966	6/89	441	456	94	$ (1995)
Zion 1 & 2	PWR	1098	1/98				No estimate
Trojan	PWR	1178	11/92	425	378	93	$ (1993)
Haddam Neck	PWR	603	7/96				No estimate
Millstone 1	BWR	684	7/98				No estimate

Source: Nucleonics Week, various.

A new feature of the estimate used in the S&W report is the inclusion of a sum for decommissioning in the completion cost estimate. This is done by estimating the cost of decommissioning and bringing it to a 'net present value', that is, the sum of money needed, which would grow to meet the amount needed in 30 years. This is a welcome development as it allows, in principle, for a full reflection of the burden of decommissioning in the project estimates. It also gives scope for arrangements to be put in place which mean that the decommissioning fund is not dependent on the plant remaining in service for the full period expected and receiving contributions from consumers at the full required rate throughout that period.

S&W chose to apply the discount rate, the rate of return required on capital, for the project as a whole to the decommissioning provisions. Implicitly, this assumes that if decommissioning provisions were set aside at the start of the plant's life they would grow at 10 per cent real (S&W's discount rate) throughout the life of the plant. This would increase their value more than 17-fold. The argument in favour of this is that a discount rate should normally apply equally to all potential resource uses at all points in the future. However, the issue with decommissioning is different. The concern is not ensuring that money is only invested in projects which offer a good rate of return on capital, but rather providing assurance that the finance for decommissioning is available when the job has to be done, more than three decades forward. This is especially necessary given that EnergoAtom has been deliberately structured in such a way that it can be privatised over the next five years (together with most of the rest of the Ukrainian electricity system). Where nuclear power is privately owned – the UK and USA are clear examples – it is good practice to set up segregated trust funds to accumulate the cash, placing it only in low risk investments, needed to undertake decommissioning. This goes some way to de-couple the decommissioning fund from the fortunes of the plant owner – if the owner goes bankrupt, the provisions made are not lost.

The relevant question then becomes the rate at which funds will reliably accumulate so that the full cost of decommissioning will be funded when required, in the third decade of the next century or later. In other words, for decommissioning we need a 'fund accumulation' rate, not a discount rate, and one based on a fairly conservative view of returns achievable for low risk investments in the market.

It is difficult to say what such a rate would be in Ukraine today. In the UK, it is assumed that the decommissioning fund run for British Energy will grow at 3.5 per cent (real) annually, while in the US, similar funds have sometimes struggled to earn much above zero. In the S&W calculation the present cost of decommissioning the two plants varies from US $ 72.6m (high completion cost and 10 per cent discount rate) to US $ 3.48m (low completion cost and 20 per cent discount rate sensitivity). Assuming a 3 per cent rate of fund accumulation (available if a fund could be invested in European index-linked government stock), then the present cost of decommissioning the two plants would rise to US $ 408m for the central estimate.

While the decommissioning cost is identified in the completion cost estimate, there is no discussion in the S&W report about how the funds identified for decommissioning would actually be treated. Given the highly uncertain state of the Ukrainian economy and of Ukrainian companies and the plans to privatise EnergoAtom at an early date, it would seem essential to identify and protect the decommissioning funds by setting up a segregated fund with the full discounted sum required from the start of operation of the plant. This would not provide an absolute guarantee that all the funds necessary for decommissioning would be available when required, but it would be much more secure than alternatives such as allowing EnergoAtom to invest the money on its own projects or relying on contributions from consumers throughout the life of the plant. However, it seems clear that in the financing of the project, there will be no financial provision for decommissioning. The EBRD's explanation of the contents of the US $ 1725m financing need for the two plants clearly contains no cash for decommissioning

The more explicit recognition of the need to take account of decommissioning responsibilities in the S&W report is welcome, but the way in which the costs are estimated is inappropriate and discussion of the practical details of how to deal with the funds is absent. More appropriate methods of estimating the decommissioning liability would significantly raise the completion cost estimate, by about US $ 300-400m.

2A.3.1.6 Construction costs and lead-time for K2/R4

2A.3.1.6.1 The new S&W cost estimates

S&W provide a range of low, middle and high estimates for the completion costs of K2/R4 (including decommissioning for both reactors and transmission reinforcement for Rovno 4 (see Table 2A.3)). These estimates are described as a result of a 'consensus agreement' reached at a meeting in Kiev in December 1997. The low or estimated case is based on the Energo-Atom project team's own estimate of project costs.

Table 2A.3: The 1998 S&W Completion Cost Estimates (1997 US $ m)

	Completion	Decommission	Transmission	Total
Estimated cost	869.4	47.3	67.0	983.7
Expected cost	1043.3	56.7	80.4	1180.4
Upper limit cost	1335.4	72.6	102.9	1510.9

For the middle estimate, described as the 'expected' value by S&W, 20 per cent is added to the low case to reflect the experience of a World Bank study of its experience of cost escalation at non-nuclear projects. The high figure involves adding a further 28 per cent to the 'expected' estimate (based on the same World Bank study). While the World Bank study is not explicitly referenced, it is almost certainly a study[12] which includes only experience of cost over-runs in non-nuclear projects. The international evidence is overwhelmingly that nuclear projects generate much larger cost over-runs than non-nuclear projects. It is desirable to conduct the kind of exercise undertaken by S&W to estimate the extent of the pronounced 'appraisal optimism' characteristic of nuclear projects. However, the lack of any nuclear projects in the World Bank study means that it is not appropriate for this purpose, and likely to perpetuate some of the optimism that surrounds cost estimates for such projects.

In one specific area, the cost of the 'modernisation' (safety upgrade) programme, there are firm grounds for treating the 'low' estimate as now highly improbable. The low completion cost of US $ 869.4m appears to be essentially the same figure as produced in November 1996 by the Project Team in Kiev (the November 1996 figure, excluding contingencies, was US $ 855 m). In that 1996 estimate, the combined 'modernisation' costs for the two reactors were US $ 185 m. However, in the approved version (Revision 2) of the modernisation programme, the combined modernisation cost has risen to US $ 327 m,[13] an increase of US $ 142 m. The value of the contingency allowance for the 'expected' cost in Table 2A.3 is US $ 174m, of which, US $ 142 m has already been used up, even before completion work has started, in escalation in the official modernisation programme cost. The 'expected' cost figure must now therefore be regarded as essentially the 'low' estimate of costs.

[12] R Bacon et al 'Estimating Construction Costs and Schedules – experience with power generation projects in developing countries', World Bank Technical Paper No. 325, Energy series, Washington DC, 1996.

[13] As outlined in detail by the IRR, 'Cost estimation for implementing the K2/R4 modernisation programme' 5 Oct, 1998.

The high cost estimate used by S&W is described as an 'upper limit'. This is illogical because the specification of an upper limit for future costs in a highly uncertain project is clearly impossible. Elsewhere in their report S&W describe the high cost estimate as representing the 90 per cent confidence level. In other words there is a 10 per cent chance that this cost level could be exceeded. However the treatment of the probabilities attaching to different cost estimates is, in yet other parts of the S&W report, misleading. The low estimate is said to have a 34 per cent probability, the central (expected) estimate a 40 per cent probability, with the high estimate having a 26 per cent probability. This is an unusual and misleading presentation of probabilities, appearing to suggest that only three outcomes are possible. In reality there is a probability distribution, as S&W implicitly acknowledge clearly in their 90 % confidence estimate. It is also important to stress that these probability distributions are dependent on judgements about future costs that are in the end subjective: for uncertain nuclear projects like K2/R4, there is no purely 'scientific' way of expressing probabilities, and the study used in support of this apparently scientific procedure by S&W is in any case inappropriate.

The 'break-even' completion cost – above which the model starts to postpone the desirable completion date for joint construction beyond 2002 – is US $ 1490 m. If, for the central cost estimate, the decommissioning cost is entered at a 3 per cent discount rate, then total project cost amounts to US $ 1451 m, a figure very close to the break-even cost level.

2A.3.1.6.2 Safety upgrades and completion costs

S&W argue that some of the uncertainties attaching to the completion costs have been resolved since the Panel made its estimate of these costs in February 1997. In particular the 'modernisation' (safety upgrade) programme is now said to have been finalised and therefore more confidence can be placed in one of the more uncertain areas of costing the completions. However, it is not clear that the modernisation programme is as final as argued. There has, for example, been no survey of the condition of the abandoned plants, and without such a survey, all cost estimates must be particularly speculative.

The estimates of completion cost used by S&W consist of three elements: cost to completion on original design; inspection of existing equipment and repair; and the modernisation or safety upgrade programme.[14] These three sets of costs have always been treated as if they are simply additive – the assumption is that they do not interact in any way. Within different possible versions of the modernisation programme the same assumption of independence is made, and each detailed 'upgrade' is treated as if it could not interact, in physical or cost terms, with any other. These assumptions are highly questionable. The very limited cost allowance for inspection and repair is a particularly vulnerable assumption, as no proper survey of the existing condition of the plant has been completed.

However, it is in the area of modernisation that S&W argue that many of the uncertainties attaching to the completion costs have been resolved since the Panel made its estimate of these costs in February 1997. The modernisation programme is now said to be finalised, and S&W argue that more confidence can now be placed in one of the most uncertain areas of costing the completions. However it is not clear that the modernisation programme is as final as argued. RiskAudit, the western consulting firm principally owned by the French and German nuclear regulators, published a final safety report on K2/R4 in December 1997.[15] However the Austrian Institute for Risk Analysis (IRR) published a critique of the plans for safety upgrades,[16] to which RiskAudit replied in May 1998.[17] The reply makes it clear that there are

[14] See Panel Report, Volume II, Supporting Paper by G. MacKerron, page 78.

[15] TACIS, 'Final Safety Assessment Report for the Loan Approval Procedure' RiskAudit Report No. 120, December 1997.

[16] Institute of Risk Research 'Safety Relevant Issues and Measures Khmelnitsky 2 and Rovno 4 IPPs' Vienna, June 1997.

[17] RiskAudit: RiskAudit Comments on the IRR Report 'Safety Relevant Issues and Measures Khmelnitsky 2 and Rovno 4 NPPs'. RiskAudit Report No. 136, 29 May 1998.

many issues on which there is not yet a final resolution, and where costs are therefore uncertain. In many of the important and potentially most costly areas, the RiskAudit reply to IRR is that 'safety issue[s] will be solved'. It is also evident that many of the safety solutions at K2/R4 will be unique to these stations, and therefore different from those already applied at Temelin or planned for Kozloduy.

2A.3.1.6.3 Comparison of different cost estimates

Completion cost estimates for K2/R4 have been made under a variety of different assumptions, and the relationship between these estimates has often been unclear. A first distinction needs to be made between 'economic' and 'financial' estimates, where 'economic' refers to real resource uses, and 'financial' refers to all costs that need to be financed before electricity can be generated from the plants. The S&W analysis is of the 'economic' variety, while the EBRD's recent figure of US $ 1725m for the whole project is a 'financial' estimate. Until recently, economic rather than financial analysis has been the norm, and it is only in a recent reply[18] to questions put by a Greenpeace representative that the EBRD has clarified the distinction. The economic estimates are dealt with first.

Table 2A.4 shows that the S&W view of completion costs has moved quite close to those put forward by the Panel in February 1997. The Panel's low figure is lower than that of S&W while the S&W figures for central and high estimates are only 6 per cent higher. This new view from S&W is undoubtedly more realistic than the earlier European Commission figure from 1996. It is however clear that no new engineering economics work has informed the newer and higher estimates. The same 'base' completion costs have simply been inflated by various forms of contingency allowance to reach the higher figures more recently published.

Table 2A.4: Estimates of the 'economic' completion cost of K2/R4 (1997 US $ m) excluding first fuel, decommissioning, interest during construction and transmission reinforcements

		Low	Middle	High
1996	European Commission		835	
1997	Surrey Panel	835	1106	1415
1997	EBRD		985	
1998	Stone & Webster	869	1043	1335

Notes: 1. Figures for the first two rows were originally in 1996 prices and have been escalated at 3 %. They also included first fuel, at US $ 130m in both cases, which has been deducted from the figures shown in this table.
2. The Surrey Panel's figures have also been adjusted to delete first fuel.
3. The 1997 EBRD figures (row 3) exclude interest during construction.

EBRD has recently offered a reconciliation between the economic costs outlined above and its estimate of financial costs of US $ 1725m. This is illuminating in some respects though it does not resolve all issues. The two main points of comparison are the S&W 'expected' economic cost of US $ 1181m (adding decommissioning and transmission as shown in Table 2A.3) and the US $ 1725m financial cost. The differences are shown in Table 2A.5 below.

[18] K2R4 Completion Project – Responses to questions raised by Anthony Froggatt in his e-mail of 10 August 1998.

Table 2A.5: EBRD reconciliation of economic and financial cost (US $ m)

Financial cost			1725
less	price contingencies	-301	
	interest during construction and fees	-212	
	first fuel	-137	
	financing assumption of sequential completion	-49	
	insurance fund for claims on installed equipment	-40	
	outstanding EnergoAtom debt	-15	
	import taxes and customs duties	-11	
	adjustment factor for contingencies	-24	
plus	allowance for 20 % cost overrun	+197	
	decommissioning	+48	
gives			
Economic cost			1181

A number of interesting issues are raised by the information summarised in Table 2A.5.

- EBRD are now making 'insurance' allowance for the possibility of claims on equipment already installed. This appears not to be genuine commercial insurance, but a kind of contingency against defects in existing construction. In November 1996, the total cost of inspection and repair of existing equipment amounted, in the European Commission completion cost estimate, to only US $ 10 m. This new figure both shows that expectations about the quality of existing work have become mores pessimistic and confirms that limited detailed information is available about the state of existing equipment. With better information, costs of repair could have been made explicit rather than estimated by an insurance analogy.
- It is not at all clear why the financial package should include the clearing of US $ 15 m of EnergoAtom debts.
- The size and use of contingencies in the estimates is obscure. The financing cost includes a total contingency of US $ 415 m, of which US $ 114m is 'physical' (i.e. refers to possible expansion in the scope of project equipment) and US $ 301 m is price contingency. It is stated that the economic cost includes only physical contingencies, but these are as much as US $ 197 m in the economic cost estimate, against only US $ 114 m for physical contingency in the financial cost. This leaves the meaning and role of the two types of contingency unclear.
- The exclusion of decommissioning from the financial estimate confirms the implication in S&W that the allowance for decommissioning in the economic cost estimate is purely notional – it is now explicit no money will actually be made available for a real decommissioning fund as part of the project finance.

It is also interesting that while S&W and the Bank both appear to accept that sequential construction of the two reactors will raise total project costs (by 5 % if a start on Rovno 4 is 18-24 months later than at Khmelnitsky 2, and by 10 % if more than three years elapse between the two projects), the Bank still wishes to observe the success of Khmelnitsky 2 before committing money to Rovno 4. This desire to delay Rovno 4 might partly result from realism about the possibility of raising US $ 1725 m in one stage, but the Bank's own explanation runs in terms of hoping for reassurance from experience at Khmelnitsky 2 that costs and times expected are really feasible. This is a sensible argument, but also has two implications that contradict the S&W analysis. The first is that the Bank regards the financial and economic uncertainty surrounding the completions to be substantially higher than the cost estimates imply. The second is that the engineering-driven view that simultaneous construction will be the cheapest option may be misguided. It is quite likely that Rovno 4 might learn from problems at Khmelnitsky and be completed at a lower cost. Such an effect could easily outweigh the savings expected from simultaneous construction, where the same error or problem could easily occur at about the same time on both projects.

2A.3.1.6.4 Lead times, including financial and contractual arrangements

In the S&W Report, Khmelnitsky 2 and Rovno 4 are due to be in full service by the start of 2002 if they are jointly completed. If construction were to be sequential, then Rovno 4 would not enter service until 2005. The EBRD subsequently decided that the plants should be funded sequentially, in which case there is now no realistic chance of Rovno 4 coming on line before 2005. If Khmelnitsky were to be delayed beyond the start of 2002, the expectation is that Rovno would be delayed by at least as long because the condition for funding Rovno 4 is satisfactory cost and time performance at Khmelnitsky 2, and this will take a minimum of three years to become apparent.

An important issue is whether it is realistic to suppose that Khmelnitsky 2 can be brought on line by January 2002 at full power, as assumed by S&W. The lead-time can be conveniently divided into pre-construction and construction phases.

2A.3.1.6.5 Pre-construction

EBRD's public consultation period of 120 days started in mid-August and will therefore be complete by mid-December. It will be impossible for any serious Bank-led public discussion of the financing of the projects to take place until a few months into 1999, allowing time to take account of the public consultation process. Only after the financial package was in place could the tendering process realistically start.

While such a financial package may be possible to construct, it is unlikely to be straightforward or easy to achieve. It may be assumed that a package is currently under negotiation, but it is difficult to predict how long it will take to complete. Experience at Temelin, Mochovce and Kozloduy would indicate a lengthy period of financial negotiation, measured in periods of years rather than months: on the other hand, the political importance of K2/R4 is such that this might speed up the process. A total of six months beyond the end of the public consultation process would seem fairly optimistic (i.e. by end-June 1999) to construct even an outline package.

Beyond this outline there is the tendering process, which will need to have significant competitive elements in it if the EBRD's normal procedures are followed. Even if the tendering process was to start in advance of completing the financial arrangements, say in March 1999, it would take some nine months to allow bidders to formulate their bids and then evaluate them. It would almost certainly take to the end of the tendering process for the export credit element of financing to be settled. This means that, even on a hopeful view of the timetable, construction work could probably not begin until January 2000 at the earliest.

2A.3.1.6.6 The construction period

The official time period for completion, when costs were expected to be US $ 941m, was 30 months. There does not appear to be a new official timetable, so, presumably, the EBRD believes that 30 months is still possible. The higher costs now anticipated must also imply a recognition of the risk of a longer construction time. However, this is not the only reason for thinking that the construction time is likely to exceed 30 months.

Experience at Temelin has been of long delays to construction (around six years) though at Mochovce, the original schedule has been little exceeded. However K2/R4 involve the same 1000 MW WWER technology as Temelin, rather than the more reliable 440 MW technology at Mochovce, and the programme of safety upgrades is more ambitious than Mochovce but less ambitious than at Temelin. Like Mochovce, it is hoped that a significant number of the safety upgrades can be postponed until after start-up, although this will have to be approved by the Regulators.

A major feature of the K2/R4 project is that it is a 'one-off' (like Temelin and Mochovce). The precise safety programmes planned are not replicas of those attempted elsewhere, and the Khmelnitsky site will have been abandoned for 10 years at the time that construction re-starts. There must be a significant risk of unanticipated problems as new safety systems and equipment are added to old equipment. The engineering estimates of November 1996 for the two reactors suggested only US $ 10m would be needed for inspection and repair, implying minimal time necessary for these tasks. Until work actually starts at Khmelnitsky 2, it will be impossible to verify these estimates and the risk that extra time may be needed is clearly large. Another potential source of delay in construction is the risk that the safety regulator in Ukraine may make more exacting demands than currently expected, especially as the regulator gains experience and is able to assert its independence. This appears to have been significant in the design changes that have been one cause of delay at Temelin.

These factors operating during the construction period suggest that 30 months is an optimistic expectation. Increases in officially expected cost since 1996, added to existing problems concerning the impact of the 10-year abandonment of the Khmelnitsky 2 site, the uniqueness of the project, and possible design changes due to more rigorous regulation, all point to delay. This could easily lead to a 12 month construction delay. Such a 42 month period, on top of a construction start itself probably delayed to January 2000 imply that Khmelnitsky 2 could not realistically be completed until end-June 2003. It is important to emphasise that the prospects for much longer delay are significant. EBRD expect to wait to confirm that Khmelnitsky 2 is successful before committing to Rovno 4. In view of the expected construction time of 30 months, the gap between starting construction of the two units would need to be at least three years. This would mean that Rovno 4 could not be ready until 2006 at the earliest. Completion dates in the 2003 to 2006 range are not serious problems in relation to Ukraine's plant needs, but they do imply that other 'greenfield' options like CCGTs might be completed by the same dates: in other words, the idea that an advantage of K2/R4 is that they offer more rapid increases in power than other options now seems unsustainable.

Any delays beyond the completion dates anticipated at the time of loan disbursements will have further financial consequences. Financially, the element of interest during construction will directly increase. In addition there is the possibility that EnergoAtom might have to start making payments on part of the loans before there is any sales revenue from the new plant, a problem that has already affected Temelin in the Czech Republic. In terms of the economic appraisal, the value of the project will fall because project benefits in terms of electricity output, which are discounted in the investment appraisal process, will have lower values at later dates.

2A.3.1.7 Fossil Fuel Prices

The future price assumed for fossil fuels, coal, oil and gas, has an important bearing on the case for K2/R4. The output of K2/R4 will substitute for power generated using fossil fuels. Therefore the higher the assumed price of fossil fuels, the bigger the savings there will be in running K2/R4 instead of existing fossil fuel plants. The price of uranium makes up only a small element of the cost of power from nuclear power plants and, as a result, will not have much impact on the case for K2/R4.[19]

There is no evidence in the last 35 years that it is possible to forecast the price of fossil fuels reasonably accurately more than a short period ahead. Most forecasts of fossil fuel prices, especially for oil and gas, have tended to assume that prices would rise due to depletion of

[19] The Panel and the new S&W report both assumed that the cost of nuclear fuel remains constant in real terms.

the world's resources. The price of fuels has occasionally risen sharply, usually in response to political events such as the Iranian Revolution, but the price has then gradually fallen back, sometimes to a lower level than before. Fossil fuel prices are now lower in real terms than before the first oil crisis in 1973.

This pattern may not continue indefinitely, but there is no strong case for assuming that the price of fossil fuels will either fall or rise over the next two decades, the period relevant for K2/R4. As a result, the Panel assumed that the price of fossil fuels would be unchanged in real terms (denominated in US dollars) throughout the period to 2010, the period over which K2/R4 were assessed.

The first S&W report of May 1997 made a strong case for K2/R4 on the basis of assumed rapid growth in fossil fuel prices. However, the second S&W report uses assumptions much closer to those of the Panel, assuming a constant real price for imported oil (mazut) and gas. The price for Ukrainian coal is assumed to fall in real terms within the next year or two by 20 per cent and no subsequent real price increases are forecast. The price reduction is the result of measures to remove the cost of social programmes, which it is hoped will assist the rationalisation of the Ukraine coal industry, from the price of coal.

One area not covered by the Panel was the cost of schlamm, the residues of washed coal expected to be burnt in the old coal-fired plant rehabilitated with atmospheric fluidised bed combustion boilers (AFBC). Although the Panel judged that the technology and the fuel source were not sufficiently well proven to include as options for a large volume of plant, the new S&W report assumes 5000 MW of conversions to AFBC fuelled by schlamm by 2005. Schlamm is assumed to be available at about a quarter of the price of gas and a third of the price of coal. We believe there is still insufficient evidence to support this over-ambitious programme (see section 2A.3.1.4). However, given that the utilisation of this converted plant is probably not much affected by whether K2/R4 are completed – this capacity could probably be operated at or near base-load in either case – the impact of this assumption is probably not of great importance to the case for K2/R4.

Sensitivity tests are included in the S&W report which envisage higher and lower than forecast fossil fuel prices. As argued above, the procedure of allocating a probability to the future price level for fossil fuels is highly dubious – it is not possible to estimate the probability for a variable which is essentially unpredictable. However, the S&W sensitivity analysis does show that if the price of gas falls by 28 per cent, the case for K2/R4, using S&W's assumptions, begins to weaken. If, as argued in section 2A.3.1.4, more realistic technical and cost data were put in for new combined cycle gas turbines (CCGTs), the case for new CCGTs as opposed to K2/R4 would be further strengthened with low gas prices.

2A.3.2 Issues not covered

2A.3.2.1 Energy efficiency measures

The S&W report takes no account of the scope for cost-effective energy efficiency measures such as those contained in the Joint World Bank and EBRD Energy Efficiency Plan (EEP), which is providing financial and other assistance to support the Ukrainian government's energy efficiency programme. The aim of this programme is to achieve annual energy savings of 109m tons of coal equivalent by 2010. The bulk of the cost-effective potential is in manufacturing industry, public services, utilities, transport and agriculture. In addition to detailed Ukrainian studies behind this programme, studies financed by the US and Dutch governments and the EU TACIS programme have all identified large scope for 'stand alone' energy savings (i.e. separate from the likely effects of industrial restructuring and modernisation of industrial processes).

The rationale for the EEP is Ukraine's very high energy-intensity due to the legacy of old, inefficient plant and equipment from the era of very low energy prices and concentration on heavy industrial output. As well as reducing economic costs, higher energy efficiency should reduce the energy import bill, environmental pollution, and the amount of new energy supply capacity needed.

The aims of the EEP are to help remove institutional, legal and other barriers and provide financial assistance to "kick-start" the government's energy efficiency programme, and "most of the activities (to be supported) can be considered as demonstration projects of high priority which may lead to mobilisation of financing on a large scale, both from the two institutions (the World Bank and EBRD) as well as from other sources".[20] Finance is to be provided in five main areas: gas and heat metering, power plant rehabilitation, district heating, energy service companies and (more tentatively at this stage) large industrial users.

At this point three objections could be raised against the idea that energy efficiency will have any bearing on the economics of K2/R4. Firstly, energy efficiency will not be easily achieved due to the depressed state of the economy and the low cash payment of electricity and other energy bills. It is true that these are difficulties, but things should improve in both respects as the economy picks up, especially as Ukraine has much higher energy prices and lower real incomes than before 1990 (in contrast to the OECD experience). Energy efficiency might therefore begin to have significant effect from about 2005 and some measures, such as upgrading the efficiency of combined heat and power (CHP) plants, could have an effect even sooner.

Secondly, although there is much scope for energy efficiency in industry, it would be a huge risk to pour money into large industrial energy users whose future is seriously in doubt. That is also true, but the EEP does not intend to do so. For the same reason, the Panel favoured targeting financial assistance for energy efficiency at essential infrastructure projects such as hospitals, schools and other public sector buildings, pumping plants, district heating and street lighting.

Thirdly, although there is clearly much scope for energy saving in Ukraine, the EEP does not separately identify the scope for and means of improving the efficiency of electricity use. To this there are three answers:

- The EBRD is helping to launch UkrEsco in 1998 with a US $ 30 m loan. UkrEsco is the first energy service company in Ukraine and will serve small and medium-sized industrial, commercial and public service clients, many of whom are "already in the pipeline". UkrEsco will implement energy (including electricity) saving projects at its own expense and receive a share of the value of the realised energy savings. Investors will be invited to tender for additional share capital with the aim of transferring control to the private sector. UkrEsco will also assist the development of the institutional framework to encourage the development of other private sector energy companies. Such companies can be a useful means of bringing private investment into energy efficiency projects. The EEP also states that the Global Energy Facility and the Global Carbon Initiative "could provide the leverage for accelerated investments in energy efficiency which might not otherwise materialise .... "these instruments would be used to create delivery and financial mechanisms for sustainable EE (energy efficiency) which can eventually be taken over and expanded in the private sector".
- To the extent that any district heating plants are renovated with combined heat and power as opposed to heat-only boilers, this should reduce the need for additional investment in central generating capacity in future.
- Although individual premises in Ukraine reportedly have their own electricity meters, individual households in many blocks of flats evidently do not have them. Any attempt to remedy this might reduce residential electricity consumption, especially where district heat is also supplied.

[20] The source of this quotation and others in this section is the World Bank and EBRD document setting out the aims and priorities of their Joint Energy Efficiency Plan.

The approach of the EEP is incremental, flexible and capable of mobilising private sector and other sources of capital, and it would certainly fit in with a 'minimum regret' strategy advocated by the Panel. It is no doubt difficult to quantify the effects of improved efficiency of electricity use for the purpose of 'least cost' modelling, but to take no account of it further strains the credibility of the conclusion that K2/R4 is 'least cost'. The commitment of the World Bank and EBRD to the EEP suggests that, in the end, efficiency improvements are likely to be 'least cost'.

2A.3.2.2 Ukraine's import dependence

The issue of Ukraine's import dependence is important, but the S&W report contains no discussion of the impacts of the K2/R4 decision on this. Gas and oil imports from Russia account for a significant proportion of Ukraine's import bill and a drain on its holdings of hard currencies. A large part of Ukraine's imports of gas (and to a lesser extent, fuel oil) is used in power stations as supplementary fuel, necessary because of the poor quality of Ukrainian coal.

Ukraine's dependence on Russian fuel is a concern not only in Ukraine but also in the West. This is reportedly a main reason why the West, in 1995, turned down Ukraine's request for loans to build a combined cycle plant in favour of offering loans for the completion of K2/R4. To an extent, Ukraine's dependence on Russian gas is balanced by Russia's dependence on Ukraine's gas pipeline system as a gateway to the West. In spite of Ukraine's difficulty in paying, Russia has so far maintained gas supplies to Ukraine.

Ukraine's attempts to modernise its coal industry, develop indigenous gas resources, improve the efficiency of its gas pipelines, build an oil terminal in the Crimea and launch its energy efficiency programme will all help to reduce dependence on Russia. In particular, if the modernisation of the coal industry enables it to produce a significant quantity of reasonable quality power station coal at a competitive price, this would ease many of Ukraine's problems of gas import dependence.

Much of the gas burnt in Ukrainian power stations is used because the quality of Ukrainian coal is currently so poor that gas is required as a supplementary fuel. The plant was designed not to need supplementary fuel and, if the quality of coal produced by the Ukrainian coal industry could be brought up to standard, a substantial amount of the gas burn could be saved. To the extent that the poor state of repair of much of Ukraine's coal fired plant is the result of the poor quality of fuel being burnt, this would also increase the reliability of the plant and reduce operations and maintenance costs.

The 'least cost' scenario identified in the S&W report has a number of implications for import dependence. The completion of K2/R4 would substitute directly for fossil fuels and therefore reduce dependence on imported fossil fuels. However, this would involve increased dependence on imported nuclear technology and fuel as well as on external financing that must be repaid. Western companies are increasing their knowledge of Soviet nuclear technology, but all major nuclear projects in Eastern Europe and the FSU have still required a major input from Russia, which, as originator of the technology, has knowledge and experience that Western companies are unlikely to be able to emulate. Western vendors are now beginning to produce fuel for Russian designed plants and this should improve the competitiveness and diversity of this market.

The major impact on import dependence of the S&W 'least cost' scenario is the proposal to convert 5000 MW of existing plant to burn mining wastes. This would substitute a locally produced resource for imported fuel. However, as argued in section 2A.3.1.4, a crash programme of conversions using unproven technology and unproven fuel sources represents a high risk option. The huge additional loans (more than US $ 3 bn) required would stretch the funds of the IFIs and represent a large capital debt for the Ukrainian generators which would have to be repaid in hard currency.

Of the plant that is assumed not to be converted to use coal waste (excluding CHP plant), 3200 MW burns gas only, and 3000 MW burns fuel oil. The rest (about 17,000 MW) is assumed to continue to require oil and gas to supplement the Ukrainian fuel. Three fuel types are assumed in the model, one with 15 per cent gas, a second with 30 per cent gas and the third with 50 per cent gas or fuel oil. In effect, the S&W report assumes that the large World Bank loans to the Ukraine coal industry fail and the commitments made to the IMF to reform the coal industry are not kept; and that, as a result, the Ukrainian coal industry is unable to improve the quality of coal produced before 2010. No justification is given for this assumption.

We strongly endorse energy efficiency measures, of the type proposed in the Energy Efficiency Plan focusing particularly on infrastructure projects such as District Heating/CHP and public buildings. This investment would give substantial environmental and economic benefits under any plausible scenario. It would also reduce consumption of electricity and fossil fuels, including imported fuel. If, as we believe, this programme is more economic than K2/R4, investing the projected completion cost of K2/R4 in energy efficiency would save more fossil fuel and reduce pollution emissions more than building K2/R4.

If there is a need for new generating capacity before 2010, then CCGTs are the most effective way, in terms of cost and emissions, of meeting this. The quantity of gas needed would be relatively small compared with the amount S&W assume would be required as supplementary fuel for existing plants. It would also represent a much less risky option than K2/R4. The supply of CCGTs is a highly competitive business and Ukraine would be able to take advantage of this to negotiate low and fixed construction costs, and guaranteed performance levels from Western vendors, benefits that assuredly will not be available for K2/R4. However, the time for such a decision is not now, since CCGTs are quick to build and there is no clear capacity need before 2010.

2A.4 New Developments in Key Areas

2A.4.1 The Economic and Electricity Demand Context

2A.4.1.1 Economic developments in Ukraine

Ukraine has experienced one of the most severe economic downturns of any of the FSU countries. Official GDP by 1996 was only 42 per cent of the 1989 (peak) level. In recent years the rate of GDP decline has slowed, but even in the most recent year for which figures are available (1996), there was a 10 per cent fall in GDP. Forecasts of future growth rates have been notoriously optimistic, even in the very short run. For instance, EBRD continued to forecast a 7 per cent decline for 1996 until late in the year 1996, against the eventual 10 per cent decline. For 1997, EBRD estimated GDP growth at -3.2 per cent. Final figures are not yet available for 1997, although the first quarter showed a year on year fall of 7.9 per cent.[21]

For 1998, earlier expectations were for marginal positive growth in GDP. EBRD expected +1.0 per cent GDP growth for 1998,[22] while Deutsche Bank Research anticipated +1.5 per cent, (both forecasts made in May 1998).[23] However, since May a major economic crisis has hit the Russian economy. Not only is 40 per cent of Ukrainian GDP dependent on trade, but some 40 per cent of all trade is with Russia, and the severe problems in Russia will inevitably have a large 'backwash' effect on Ukraine, mainly through sharply falling exports. This suggests that the forecasts that GDP will finally grow in 1998 will almost certainly turn out to be

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[21] MC Securities Ltd Ukraine Electricity Privatisation: Power to the People? 17 September 1997, page 13.

[22] Quoted in FT East European Energy Report (FTEEER), May 1998, 80/16.

[23] Deutsche Bank Research, Emerging Markets, Ukraine, 26 May 1998.

strongly optimistic. Longer-term forecasts of GDP have tended to be even more optimistic than of current-year GDP. The predominant expectation early in 1998 was for growth of 2-3 per cent for 1999 and 2000, but such performance – already partly dependent on progress with economic reforms and the attraction of more foreign investment to Ukraine – now seems in any case unlikely in view of the depth of the Russian economic crisis.

However, the formal economy is not all that matters. Ukraine has a particularly large informal or unrecorded economy. This has clearly grown since 1991, but by definition it is impossible to be sure of its total size. World Bank estimates suggest that the informal economy may be as large as 46 per cent of all economic activity, though it is not clear whether the sector is continuing to grow significantly. From an energy perspective, any growth here is probably of more limited importance than in the recorded economy, because informal activity is unlikely to be energy-intensive.

In the monetary economy, Ukraine's position is mixed. Inflation has been successfully reduced from very high levels to around 20 per cent per annum, and the balance of payments has been better than expected due to improved export performance, at least up to 1997. However, levels of both internal and external debt are rising rapidly. In 1998 total debt service (internal and external) will be almost 40 per cent of budget revenues[24] (27 per cent in 1997) and this is why it was critical for Ukraine to acquire the US $ 2.2 bn of Extended Fund Facility (EFF) that the IMF approved in September 1998. The problem is compounded by the fact that a higher proportion of the external debt is now owed to Western sources, especially international organisations. In the early 1990s a very high proportion of external debt was owed to Russia, especially to Gazprom, and such debts have been re-scheduled several times. However, as debt has risen, a growing proportion belongs to Western sources, including the multilateral banks, and, in these cases, creditors have been much more reluctant to engage in significant re-scheduling.

Privatisation and structural reforms are official policy, but have not made much headway to date. The conditions of the IMF's EFF signed in September 1998 required that Ukraine continue to make these changes a priority, but the changed complexion of the Ukrainian Parliament after the March 1998 elections, and the run-up to Presidential elections in 1999 may have an impact on these processes.

2A.4.1.2 The Organisation of the Electricity Sector

Ukraine started a major structural reform of its electricity system in 1994, when transmission was separated from generation and distribution, and the fossil-fired generating plant was organised into four generating companies that are supposed to behave competitively. There are in addition two hydro companies, the large nuclear generator EnergoAtom, and 27 distribution companies which own some 15 per cent of all thermal plant. An attempt was made after 1994 to introduce a structure for the wholesaling of electricity resembling that of England and Wales. The seven generating companies make price bids into a Pool, and the marginal plant determines the system price, though capacity payments may also be added when capacity is tight. It is planned that generators will at some point be allowed to sell power directly to large customers, through a third party access system, but there is no clear timetable for this. There is in addition an economic regulator, the National Electricity Regulator, with legal responsibility for licensing, prices, competition and service levels.

In practice, the Pool market does not act to determine wholesale electricity prices. First, there is substantial government intervention in the market. Thermal plant is not permitted to bid at higher than 3.1c/kWh, although early thermal bids were frequently in the range 4-5c/kWh. Nuclear plant can bid no higher than 2.4c/kWh. Second, in the cash-short Ukrainian economy, wholesale electricity bills – payable by the state-owned distribution companies – are

[24] Deutsche Bank Research, op.cit., p. 3.

rarely paid in cash or on time. It is estimated that some 20 per cent of bills are paid in cash, 60 per cent are paid by barter and 20 per cent are simply not paid. The barter system generally works by a trading company purchasing fuel and then bartering it to generators in return for a large (possibly 30 per cent) discount on electricity supplied to the trading company.[25] Barter therefore yields fewer resources to generators than even the constrained Pool prices imply. The Pool system is therefore some way short of a functioning market.

The nuclear sector was reorganised in 1997 and 1998. In June 1997, a reorganised Ministry of Energy absorbed Goskomatom, the former state nuclear energy agency, and took responsibility for radioactive waste, the fuel cycle and Chernobyl. A new company EnergoAtom took responsibility for the operation and management of the other nuclear stations. EnergoAtom had some initial problems, partly due to the tradition that nuclear station managers had considerable autonomy, and in March 1998 the company was 're-launched'.[26] The station managers are now members of EnergoAtom's Board but are also now directly responsible to the Board. The hope is that with a proper corporate structure, EnergoAtom may be privatisable in around five years.

The generating and distribution companies are now a major part of the attempt to privatise large parts of the Ukraine economic system, though progress to date has been strictly limited. In September 1997, privatisation plans for electricity were announced: initially two or three of the thermal generators were to be privatised, plus up to 12 of the distributors.[27] The government planned to retain at least 51 per cent of shares (later reduced to 26 per cent in the case of distributors), with 17 per cent to 23 per cent distributed to employees, and 26 per cent to 32 per cent reserved for private interests, preferably 'strategic' overseas investors.[28] The method to be used was the 'non-commercial' tender, allowing considerable scope for intervention by government in determining the buyer.

By the end of 1997, up to seven companies were said to be ready for privatisation, including 24 per cent of the generator Donbassenergo. However, early in 1998 the original tendering plan for Donbassenergo was scrapped, after Parliamentary intervention, and new tenders were invited. By April, the whole electricity privatisation process was halted. This was apparently because the sales values were thought to be too low by government, though it was also the case that of seven offers, bids had only been received for two companies. The privatisation process was supposed to re-start in May, under more restrictive conditions than before: investors were to be disallowed from re-selling shares for five years and had to have energy market experience.[29] This is likely to make the sales even more unattractive, and to induce even lower price offers on the part of prospective investors. The only real successes of the privatisation programme so far have been: a joint venture (51 per cent owned by Northland Power of Canada) won a contract to refurbish a multi-fired CHP plant, under a Build-Operate-Transfer arrangement; and, in August 1998, a Cyprus-based consortium, Overcon, won a tender to buy 35 per cent of the Odessaoblenergo. But this is a very modest amount of progress in the privatisation process. Without a major relaxation of the terms on which investors can bid, and a more transparent bidding process, the privatisation of electricity companies seems likely to make little headway.

So far the decisions of buyers of electric power seem to have had little weight in determining what type of capacity is contracted for in the future. No evidence of free market interest in completing K2/R4 to replace Chernobyl has ever been presented.

[25] MC Securities Ltd Ukraine Electricity Privatisation: Power to the People? 17 September 1997, pages 69-74.

[26] FTEEER, March 1998, 78/22

[27] FTEEER, September 1997, 72/13

[28] MC Securities op. cit.

[29] FTEEER, April 1998, 79/8.

Assuming that K2 and R4 are completed, which will not be before 2005, the financial viability of EnergoAtom will be in question because of the risk of cost and time over-runs at K2/R4. If K2/R4 then operate reliably, this will give EnergoAtom an electricity market share of more than 50 per cent – all the base-load – leaving the other six generating companies only small market shares to compete for. Completing K2/R4 may therefore postpone the possibility of privatising EnergoAtom until after 2005. The reduced market share available to the other generators and the heavy burden of rehabilitation work they need to undertake will make the other generating companies difficult to privatise until electricity demand starts to grow strongly or the older nuclear plants are retired.

2A.4.1.3 Non-payment of electricity bills

Non-payment and the low level of payment in cash are the most serious problem of Ukraine's electricity industry. This is a problem that also affects other parts of the energy sector and other industries. The basic cause is the poor state of the economy, including the difficulties of the state-owned large industrial sector, very high interest rates, extensive non-payment of wages and salaries, and the large fall in real wages.

Non-payment by domestic consumers is only a small part of the problem, residential payment levels being around 70 per cent – much higher than in the industrial sector. Utility collection rates are therefore comparatively high in western Ukraine where the proportion of electricity sales to industry is low. Rural consumers with separately metered premises tend to be better payers than urban consumers living in flats where only the total electricity consumption in the apartment block is metered. For obvious social reasons, people who have not been paid their wages or salaries are legally allowed not to pay their utility bills; disconnection of households is allowed only in summer months, winters in Ukraine often being severe; and in a country with no government welfare system to speak of, disconnecting pensioners who cannot pay would be politically unacceptable.[30]

Industry represents a far bigger part of the non-payment problem, especially the state-owned basic industries whose collapse could lead to mass unemployment and political unrest. The move to a pool-based wholesale power market has tended to equalise non-payment across the four fossil fuel generators, although non-payment remains high for generators that sell some of their output to large industrial users.[31] Barter forms a much higher proportion of the total payment of electricity bills than cash. The fossil fuel and nuclear generators are themselves major participants in the barter trade, with trading companies buying the fuel for them (usually from Russia) and in return receiving title to electricity at a discounted price; the trading companies then re-sell the electricity, often to large state-owned companies, at a considerable profit in terms of barter goods which are then traded on through an extended bartering chain. In the process the government loses expenditure tax revenue and does not benefit from the discounted price of electricity.

The effects of the non-payment problem were emphasised to the Panel in interviews in Ukraine in October 1996. Up to that time the problem was underestimated in the West largely because it was grossly under-recorded in electricity company accounts. The average non-payment for the distribution companies was recorded as only 5 per cent in 1995 and 4 per cent in 1996, but the Ministry of Economy put the figure at 44 per cent in 1997.[32] In the context of the Financial Recovery Plan in April 1998, with the aim of securing the second tranche of the World Bank loan for working capital purposes, the government published the information summarised in Table 2A.6 which shows all parts of the industry, including nuclear power, as being subject to significant levels of non-payment, high levels of barter payment, and low levels of cash payment.

[30] MC Securities op. cit

[31] MC Securities op. cit

[32] MC Securities op. cit

Table 2A.6: Collection rates of electricity bills, February 1998 per cent of electricity bills by value (January 1998 figures in brackets)

	Distribution companies		**Four fossil fuel generators**		**EnergoAtom**	
Cash	11.6	(7.8)	5.6	(7.0)	5.7	(5.8)
Other (barter)	72.4	(47.5)	132.7	(54.0)	59.7	(38.1)
Non-payment	16.0	(44.7)	n.a.	(39.0)	34.6	(56.1)

Note: The figure for payment to the fossil fuel generators in the 'other' row implies that barter payments in February were high with some catching up on arrears to the fossil fuel generators.

Source: 'On approving Financial Recovery Plan for the power sector of Ukraine'. Resolution of Cabinet Ministers of Ukraine, 18th April 1998.

Numerous measures are outlined in the Financial Recovery Plan to deal with the problem, including suspending or reducing supply to non-payers, prosecution of corporate and municipal non-payers and the scheduling of corporate debt repayments. The document also reveals other aspects of the problem, including the withholding of payments within the electricity industry itself, e.g. by the distribution companies, of money owed to the generators via the pool settlements system – presumably to be deposited for a time at very high interest rates. Also some money owed to the pool is reportedly used for government expenditure purposes, partly to make up for the loss of expenditure tax revenue which is evaded by the barter arrangements.

The outlook for the winter of 1998/99 is grim: the power stations cannot stock up with sufficient fuel for the winter and no remedy is in sight. According to Ukraine's energy minister, Oleksiy Sheberstov, "There is simply nothing with which to buy the fuel, because 20 per cent of all the electricity generated goes to consumers free of charge. We cannot shut down mines and engineering plants, or the infrastructure of villages and cities, whose debt to the generators amounts to 70 per cent of the total". He also ruled out raising electricity tariffs for residential consumers in the near future.[33]

It has yet to be seen how much difference the Financial Recovery Plan will make to the non-payment problem. A solution seems unlikely until economic recovery and industrial restructuring are well underway and cash and credit are circulating freely through the economy. But these are almost certainly a good few years away. Disconnections of non-paying domestic consumers are certainly not the solution; nor is raising the price of electricity.

Non-payment and barter payment severely distort the electricity market. At any given level of economic activity, electricity demand will be significantly lower when all customers have to pay their bills in full and in cash. Meanwhile, this market distortion represents a large risk in investment appraisals for fixed investment in additional generating plant, though the risk is somewhat lower with investment in energy efficiency projects of the types proposed under the Joint World Bank and EBRD Energy Efficiency Action Plan (see section 2A.3.2.1), since they seek to anticipate conditions when economic recovery takes place and when electricity tariffs convey more meaningful price signals to Ukrainian electricity consumers.

2A.4.1.4 Loans to Ukraine and their implications for the completion of K2/R4

This section assesses progress in providing loans to Ukraine to guarantee the closure of Chernobyl by 2000. It examines recent loans from the international financial institutes (IFIs) and Euratom to Ukraine, in particular those relevant to the electricity sector and the completion of K2/R4. The IFIs of particular relevance are the EBRD and the World Bank, although

[33] Quoted in FT East European Energy Report, August 1998 83/27.

the International Monetary Fund (IMF) is also of importance here because of its role in helping countries in financial difficulties. The IMF's position will therefore have a key part in determining the credit rating of Ukrainian organisations, especially those owned by the central government, and may determine whether loans are possible.

Table 2A.7: Loans to the Ukrainian Energy Sector from IFIs and Euratom

Project	IFI	($m) IFI Contribution	Comments
Electric market	World Bank	317	Working capital loan, suspended development since November 1997
Starobeshevo	EBRD	113	No progress in letting equipment rehabilitation contracts. Progress suspended since November 1997
Kiev district heating	World Bank	200	
rehabilitation	EBRD	40	
Energy Service	EBRD	30	Under negotiation
K2/R4	EBRD	190	
	Euratom	480	
Total	**EBRD**	**373**	
	World Bank	517	
	Euratom	480	
Grand Total		**1370**	

The Memorandum of Understanding (MOU) signed by the G7, the European Commission and the Ukraine government in December 1995, required that the IFIs and Euratom provide loans amounting to US $ 1.8bn (including some already being negotiated then) for investment in revenue earning projects in the electricity sector of Ukraine. These were to be allocated according to 'least cost' planning principles. A list of priority projects was appended and this included completion of K2/R4, rehabilitation of thermal power plants, completion of the Dniester (also known as Dnistrovska) pumped storage plant and energy efficiency and demand side management measures. While there was no time limit within which this money had to be committed, the Ukrainian side of the deal, the closure of Chernobyl by 2000, implied early commitment of these resources.

Table 2A.8: Selected Loans and Grants to Ukraine from IFIs

Project	Lender	($m)	Date	Comments
LOANS				
Kiev district heating rehabilitation	World Bank EBRD Various (Kiev)	200 40 68.9	5/98	Improving heat production, rehabilitating network, institutional support
Coal sector adjustment	World Bank	300	12/96	To help finance coal sector restructuring including social mitigation and safeguarding viable portion of the industry
Starobeshevo modernisation	EBRD Export credit Ukraine	113 21 29	12/96	Replacement of conventional boiler at 210 MW Starobeshevo power plant with atmospheric fluidised bed boiler
Electric market development	World Bank	317	10/96	Essentially provides working capital for fuel and spares for 14 thermal power plants Also to help with metering, billing, training and to develop a privatisation programme
Coal pilot project	World Bank	15.8	5/96	Pilot project to help mitigate social and environmental consequences of mine closures
Hydropower plant rehabilitation	World Bank	114	4/95	Rehabilitation of hydropower plants and improvement of power control systems
Gas Metering	EBRD	80.6	12/97	Enables UkrGas to acquire and install 1 million residential and commercial gas meters throughout Dnipropetrovsk and to improve its billing and collection capability
GRANTS				
Consulting services for Shelter Implementation Plan	EBRD CSF	Not known	7/98	Award to ICC Joint Venture which comprises BNFL (UK), Morrison Knudsen (USA) and three Ukrainian organisations
Project management work	EBRD CSF	30	3/98	Award to EnergoAtom
Setting up Chernobyl Project	EBRD CSF	41	3/98	PMU comprises Electricite de France, Bechtel and Battelle
Management Unit (PMU) Chernobyl closure plan	EBRD NSA	131	10/96	Preparation for closure of Chernobyl including decommissioning facilities and short-term upgrades to unit 3 (8 % of funds). The latter was cancelled in February 1998

2A.4.1.4.1 The IMF

The IMF lends money to members having trouble meeting financial obligations to other members, on condition that they undertake economic reforms to eliminate these difficulties. It thus has considerable leverage over countries forced to seek its assistance and loans from the IMF may be a key factor in determining the terms of project loans with other IFIs.

Ukraine joined the IMF in September 1992 and, by October 1994, its balance of payments and inflation difficulties forced the government to negotiate a Systemic Transformation Facility (STF) from the IMF, the first instalment of which gave it credits of nearly US $ 400m for 1994/95. This was followed in April 1995 by a second instalment under the STF, also of nearly US $ 400m, and a one-year Stand-By Credit of US $ 1.57bn for 1995. This in turn was followed in May 1996 a nine-month Stand-By Credit of about US $ 867m and in August 1997 by a further one-year Stand-By Credit of about US $ 550m. A particular problem has been the level of internal and external debt. Servicing this debt in 1998 will absorb almost 40 per cent of budget revenues. It had been hoped in 1997 that the one-year arrangements could be replaced by longer-term support under a three-year Extended Fund Facility, but domestic consensus could not be reached then.

In July 1998, provisional agreement was reached between the IMF and the Ukraine government for an Extended Fund Facility (EFF) of about US $ 2.2bn for the three year period following the expiry of the Stand-By Arrangement. This is expected to help Ukraine attract further foreign credits into the Ukraine economy and improve its credit rating which, in the summer of 1998, had fallen significantly. One of the factors mentioned by the IMF Mission that negotiated the deal, and that contributed to its recommendation of this facility, was the plans for further reform of the energy sector, especially the coal sector. The plan was expected to be put to the board of the IMF in August, but the potential knock-on effects of the financial crisis in Russia delayed consideration until September 4, when the loan was approved.

2A.4.1.4.2 The World Bank

Ukraine joined the World Bank in 1992 and, by May 1998, the World Bank had made commitments worth over US $ 2.2bn for 14 projects. The World Bank does not lend money for nuclear power projects and therefore cannot directly participate in the financing of K2/R4, but can contribute to the total package of loans.

Amongst the 14 projects supported, a number are related to the electricity sector, notably the US $ 317m loan agreed in October 1996 to provide working capital to buy fuel and spares for power plants for the fossil fuel electricity generation sector. This loan, which can probably be categorised as contributing to the rehabilitation of the power plants mentioned in the MOU, remains by far the largest loan firmly committed as part of the US $ 1.8bn promised. However, in autumn 1997, the World Bank suspended the second tranche of the working capital loan, following the government's failure to raise power tariffs. Subsequently the World Bank negotiated a Financial Recovery Plan published by the Ukraine government in April 1998. This sets out measures to increase the cash payment for electricity, reduce barter, and put in place market-based retail tariffs. However, release of the second tranche of the working capital loan was delayed until after the signing of the IMF agreement. By the end of September 1998, the second tranche had still not been unfrozen. The World Bank has also agreed major loans to support the reform of the coal-mining sector (see Table 2A.8), but these would not form part of the US $ 1.8bn package.

The most recent project is the plan, agreed in May 1998, to rehabilitate the Kiev district heating system. About 65 per cent of the cost will come from the World Bank, a further 22 per cent will come from local sources in Kiev and the remaining 13 per cent from the EBRD. The economics of this rehabilitation programme do not appear to have been tested in the S&W study.

The World Bank had been reported to be considering funding completion of three units at the Dniester pumped storage plant,[34] but in September 1998 it abandoned these plans. This plant comprises seven units of 324 MW and is reported to be 70 per cent complete. Using its electricity system simulation model, EGEAS, the S&W report found no economic case for completing this plant, while the earlier Lahmeyer report concluded that it was a 'least cost' investment.

2A.4.1.4.3 The EBRD

The EBRD was set up in 1991 to provide loans to Eastern Europe and the FSU. It is involved in providing loans to Ukraine from its own funds and it provides grants in its role as the administrator of the Nuclear Safety Account (NSA), set up in 1993, and the Chernobyl Shelter Fund (CSF), set up in November 1997, both of which are funded mainly by the G7 countries (see box for an account of the NSA and the CSF).

The EBRD already has a sovereign exposure (state guaranteed loans) of ECU429m in the country and will only agree to release funds for K2/R4, at the earliest from autumn 1999, if Kiev complies with the Financial Recovery Plan negotiated between the World Bank and the Ukraine government.

From its loan funds, EBRD had financed only one project in the electricity sector by the beginning of 1998, the upgrading of the Starobeshevo unit 4 (210 MW) plant, agreed in 1996 and scheduled to be complete in 2000. This involves replacement of the conventional boiler with an AFBC boiler which allows the plant to use a mixture of the residue from coal washing plants (85 per cent) and unwashed coal (15 per cent). The EBRD clearly sees great potential for this technology in Ukraine, and the S&W study finds a strong case for upgrading 5000 MW of plant in this way by 2005. If the Starobeshevo cost figures prove to be accurate, this would require an investment of about US $ 3.4 bn. No equipment orders have yet been placed for the Starobeshevo project and it may be difficult to meet the expected completion date of the end of 2000 contained in the S&W report.

The EBRD is currently working with the Ukraine State Committee for Energy Conservation to provide financial assistance for energy efficiency projects, including energy service companies, district heating and metering. The loan involved would probably be about US $ 30 m (see section 2A.3.2.1).

2A.4.1.4.4 Implications for financing K2/R4

When the Panel conducted its study, it was expected that the cost of financing K2/R4 would be US $ 1.2bn. This was to be met mainly by the Euratom division of the European Commission, (38 per cent) and the EBRD (31 per cent). The balance was expected to come from the Ukrainian government (15 per cent) and export credit agencies (17 per cent). Despite escalation in the estimated cost of completion to over US $ 1.7bn, the EBRD's expected contribution has fallen. In April 1998, the EBRD was reportedly willing to provide only US $ 80m because of its wish to concentrate its funds on private sector deals.[35]

In June 1998, the EBRD provisionally approved funding for K2/R4 on the basis of the S&W report, subject to a public consultation process in Ukraine and a maximum EBRD loan of only US $ 190 m (an 11 per cent share). The EBRD money is conditional on Ukraine complying with the Financial Recovery Plan agreed with the World Bank in April 1998. The funds will only be provided if one of the plants (Khmelnitsky 2) is completed before work on the other is started and so the immediate problem is financing this unit, expected to require that US $ 865 m be raised (see Table 2A.9).

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[34] Eastern European Energy Report 'Company formed for Ukrainian hydro plant' June 1998, p 46, Financial Times Energy, London

[35] Nucleonics Week 'Though K2/R4 is least cost option, EBRD now wants to limit lending', April 9, 1998, p 1.

Table 2A.9: Financing for K2/R4

	1997 (K2/R4)		1998 (Khmelnitsky only)	
	US $ m	**Share (%)**	**US $ m**	**Share (%)**
Euratom	456	38	240	28
EBRD	375	31	95	11
Ukrainian government	175	15		
Export Credit Agencies	200	17		
Russia			180	10
Total Required	**1200**		**865**	

In the light of the commitment to Rovno, the EBRD will presumably wish to commit only half its available resources, US $ 95m, to Khmelnitsky. Euratom can raise up to ECU1.2 bn (about US $ 1.3bn) but as it is also keen to fund completion of Kalinin 3 in Russia and the upgrading of Kozloduy 5 and 6 in Bulgaria, it is unlikely to offer more than US $ 480 m (28 per cent) for K2/R4.[36] Unless Euratom would want to bear more than half the financing cost and would wish to leave itself with no resources to contribute to Rovno completion, no more than half of this sum would be available to Khmelnitsky.

The EBRD expects that some US $ 365m worth of equipment and supplies would be needed from foreign suppliers for Khmelnitsky, half from Russia and half from the West. Russia has indicated its willingness to provide the equivalent of US $ 180m (probably in kind, not cash) to the project, although the current financial crisis in Russia puts this contribution in doubt. Even if this full amount is available for Khmelnitsky, that still leaves US $ 350 m to be found from the Ukraine government and export credit agencies. Financing Rovno 4 will hardly be easier, especially if the Khmelnitsky project does not go smoothly or the Ukraine economy does not begin to recover strongly.

2A.4.1.4.5 Conclusions

On the face of it, the change from simultaneous to sequential completion of K2/R4 would seem to ease the problem of financing the first unit. However, a combination of escalation in the completion cost estimate and a reduction in the expected contribution of EBRD mean that the sum to be raised for this first unit from sources other than EBRD and Euratom may be as much as was previously expected to be required for the two units. Experience at Temelin and Mochovce, both of which took several years to assemble a funding package, and the serious financial difficulties that the Ukrainian economy is meeting, are unlikely to encourage other potential funders to participate.

On the broader issue of the US $ 1.8bn loans promised to Ukraine in the MOU, the contribution of the IFIs and Euratom to projects already approved or being negotiated (see Table 2A.7) is some way off the target of US $ 1.8 bn (in 1996 money). Most of the loans fall into the categories listed in the attachment to the MOU, but only about 35 per cent of the funds are reasonably firmly committed. Western funding for the Dniester project does not now appear likely and the largest element, K2/R4, is still far from agreed. The Western-funded projects, especially Rovno 4, are continuing to slip well beyond 2000 and are clearly not in any physical sense 'replacements' for Chernobyl. The Starobeshevo project does nothing to address the severe problem of the poor condition of all the other fossil fuel plants in Ukraine. To some extent, the World Bank working capital loan was meant to address the problem of the poor condition of plants, but it is not clear how much of this will now go into enhanced maintenance of the type needed. The S&W report implicitly addresses the problem of the poor con-

[36] Financial Times Energy Economist 'K2R4: Cutting the Gordian knot', July 1998, pp 7-14.

dition of plant by a grandiose plan to rehabilitate 20 similar plants to Starobeshevo by 2005, a programme that would require an investment of US $ 3.4bn – provided that the new privatised owners of these plants are happy to take on this amount of debt for a technology which is not sufficiently proven (see section 2A.3.1.3).

THE NSA AND THE CSF

The NSA

Unlike the normal funds disbursed by the EBRD, payments from the NSA are grants, not loans, and are aimed at improving the safety of nuclear power plants in the Former Soviet Union and Eastern Europe. By December 1997, pledges to the NSA amounting to ECU261 m (about US $ 290 m) had been made by 14 countries and the European Union (EU). Projects in four countries, Ukraine, Russia, Bulgaria and Lithuania have been approved, of which much the largest is the ECU118.1 m grant signed in 1996 to allow the closure of Chernobyl (see Table 2A.8). About 8 % of this grant was to have been to allow short-term safety upgrades at the one unit then still in service at Chernobyl, unit 3, to allow it to operate safely until 2000, but this proposal has now been abandoned. The record of the NSA has been controversial with criticisms that it has been ineffective in meeting its goals. In May 1998, it cancelled a project agreed June 1995 for short-term upgrades at three plants because little progress had been made in starting the work. The plants were of designs which the West hopes to ensure are closed soon because of safety deficiencies – two were of the Chernobyl design (RBMK) and one was of an early WWER design.

The CSF

The CSF was designed to assist Ukraine in ensuring that the existing Chernobyl sarcophagus would become a safe and environmentally stable system. The CSF is still in the early stages of elaboration although the Shelter Implementation Plan (SIP) had been under development since May 1997. At December 1997, the EBRD had received pledges of contributions of ECU263m (about US $ 300m) from various OECD countries and the EU. Subsequently a number of other countries have made pledges. The total sum required is expected to be about US $ 800m and will involve some 22 separate projects. The first grant of ECU28 m was signed in March 1998 to set up a Project Management Unit (PMU) which is a consortium of Electricite de France, and two American organisations, Battelle and Bechtel (see Table 2A.8). Contracts have since been agreed between the PMU and EnergoAtom, the Ukraine nuclear power utility, and also with a Western joint venture headed by BNFL (UK).

2A.4.2 Specific Evidence Relevant to K2/R4

2A.4.2.1 The Operating Performance of Nuclear Power Plants in Ukraine

In this section we examine the performance of the nuclear power plants in Ukraine, focusing particularly on those of the WWER-1000 design (see Table 2A.10).[37] We also include the remaining unit at Chernobyl and the two 440 MW units at Rovno which use an earlier version of the WWER design. The WWER-1000 units have an electrical output of 1000 MW and are similar in concept to the pressurised water reactor (PWR), which is the main design used in the West. This is the design that was chosen for Khmelnitsky 2 and Rovno 4 (K2/R4) and was also used for 11 of the operating nuclear units in Ukraine (South Ukraine 1 and 2 use earlier models of the WWER-1000 ('302' and '308'), but are very similar to the latest design, the '320'). After closure of the one remaining unit at Chernobyl, the WWER-1000s will represent more than 90 per cent of the nuclear capacity in Ukraine whether or not K2/R4 are built. The performance of this design will therefore largely determine the contribution nuclear power can make to Ukrainian electricity supplies over the next decade or two.

Table 2A.10: Nuclear Power Plants in Ukraine

Name	Technology	MW	Start of Construction	Commercial Operation
Chernobyl 3	RBMK-1000	925	1977	1982
Khmelnitsky 1	WWER-1000/320	950	1981	1988
Khmelnitsky 2	WWER-1000/320	950	1985	-
Rovno 1	WWER-440/213	361	1976	1981
Rovno 2	WWER-440/213	384	1977	1982
Rovno 3	WWER-1000/320	950	1981	1987
Rovno 4	WWER-1000/320	950	1986	-
South Ukraine 1	WWER-1000/302	950	1977	1983
South Ukraine 2	WWER-1000/338	950	1979	1985
South Ukraine 3	WWER-1000/320	950	1985	1989
Zaporozhe 1	WWER-1000/320	950	1980	1985
Zaporozhe 2	WWER-1000/320	950	1981	1985
Zaporozhe 3	WWER-1000/320	950	1982	1987
Zaporozhe 4	WWER-1000/320	950	1984	1988
Zaporozhe 5	WWER-1000/320	950	1985	1989
Zaporozhe 6	WWER-1000/320	950	1986	1996

[37] Two sources of data are used to analyse operating performance. Nucleonics Week publishes monthly electricity generation figures for each plant about a month in arrears. From this, it is possible to calculate load factors. The Panel's report was therefore able to use full year data up to the end of 1995 and data up to the end of August 1996. This report utilises the data for the whole of 1996 and 1997 and the first six months of 1998.

The second source of data is published by the International Atomic Energy Agency (IAEA 'Operating experience with nuclear power stations in member states in 1996', IAEA, Vienna) which gives a much more detailed account of annual performance, from which measures such as breakdown frequency can be calculated. It lists the date, cause and duration of all outages. This is published about a year in arrears and so data for 1996, not available to the Panel in its report, can be used in this analysis.

The operating performance that can be expected from plants of the WWER-1000 design is of key relevance to the economic case for K2/R4 and also has significant implications for their safety. All things being equal, the higher the level of output that can be expected from K2/R4, the stronger will be the case for completing them. In a situation such as that in the Ukraine where there is no nominal shortage of generating capacity, the argument for K2/R4 rests on the overall cost of generation, including the capital cost, from these two plants being less than the operating cost of the plants it will not be necessary to use if K2/R4 are completed. The case for K2/R4 therefore depends not only on the costs associated with completing and operating these new plants, but also on the operating costs that would have been incurred in the plants that they will replace. These would generally be expected to be the most expensive plants to operate on the system.

2A.4.2.1.1 The International Performance Context

The economic success of nuclear power is crucially dependent on the amount of electricity they produce each year, because the cost per unit of electricity generated is dominated by fixed costs, largely those associated with their construction. The more output the plant generates, the more thinly these costs can be spread. The main indicator of operating performance is the annual load factor (or, in US parlance, capacity factor). This is calculated as the output produced by the plant in a year expressed as a percentage of the output the plant would have produced had it operated uninterrupted at full power throughout the period. When the first commercial orders for nuclear power plants were placed in the 1960s, it was expected that reliability would be good and the load factor assumed in economic appraisals was usually about 85 per cent.

These expectations proved too optimistic and through the 1970s and 1980s, the world average was 70 per cent or less. Since then, there have been strong efforts to improve performance and, while there is still variability from country to country, the average for Western plants is now about 80 per cent.

A second important determinant of the economic success of a nuclear plant is its winter peak availability, which is a measure of the amount of power that can be expected at the annual peak in demand. This is an important parameter because, even if a plant has a relatively good annual load factor, if it is not reliable when it is needed most, at peak time, its value to the system will be diminished. In this analysis, the average load factor in January and February, a period when no routine maintenance would be scheduled, is taken as a measure of winter peak availability.

A third useful measure of performance is the annual breakdown frequency. This is calculated as the number of times a plant breaks down in a year, normalised to 6000 hours on-line. Thus, if a plant is producing power for only 3000 hours in a year and breaks down twice, the normalised breakdown frequency is 4. From an economic point of view, a low breakdown frequency is important for two main reasons: first, it is likely to be reflected in low repair and maintenance costs; and, second, it will tend to reduce costs incurred in having stand-by power plants ready to cover for plant break-downs.

From a safety point of view, a low break-down frequency is also highly desirable for a number of reasons. A low breakdown frequency is likely to be the consequence of high quality maintenance, which, in turn, is likely to correlate with high safety standards. Good reliability also minimises the number of times when the plant has to be started up or closed down. These operations place thermal stresses on the plant which will tend to reduce its life-time, and they also place the operating staff under more pressure than routine operation – operator errors are more common during start-up and shut-down than in routine operation.

There is wide variability from country to country, but the average breakdown frequency for Western plants, which like load factor has improved markedly in the last decade, is about 3. The most reliable plants, such as those in Japan and Germany, average less than 1.

2A.4.2.1.2 WWER-1000s

Plants of the WWER-1000 design are also in service in Russia (seven units) and Bulgaria (two units). The performance of units of this design is seldom better than mediocre, wherever they have been installed (see Table A2.11). The plants in Ukraine have a somewhat better record than those in Russia and Bulgaria, with the 11 Ukrainian plants having a mean lifetime load factor up to the end of 1996 of 63 per cent, while those in Russia and Bulgaria average 56 per cent.

Table A2.11: WWER-1000 Performance in Ukraine, Russia and Bulgaria

Year	Ukraine	Russia	Bulgaria
1996	62.4	51.4	60.3
1997	71.9	52.7	53.9
1998 (to end June)	73.5	67.4	76.9

However, there is some variability from year to year and it is important to look at the most recent data to identify any trends. In its report, the Panel assumed that the 11 existing Ukrainian WWER-1000s would continue to operate at the same average load factors as they had reached in the three most recent years for which data was available, 60 per cent. K2/R4 are of the same basic design as the other 11 Ukrainian WWER-1000s and it is not planned that there will be major reconstruction work systematically replacing Russian equipment with better quality Western equipment, such as has occurred at the Temelin plant in the Czech Republic. There did not therefore appear to be any justification for assuming dramatically different performance for K2/R4 than for the other 11 units. The Panel assumed that Western involvement in the completion of the plants and improved management would lead to higher standards of construction and operation, and this would increase the average load factor to 67.5 per cent for K2/R4.

The impact on the economic case for K2/R4 of the assumed level of performance of the WWER-1000 plants cannot readily be predicted. An assumption of good operating performance for K2/R4 would, all things being equal, tend to improve the case for them. However, as argued above, it is not likely that the performance of K2/R4 can be dramatically better than that of the other 11 plants. If it is assumed that K2/R4 will perform relatively well, for example, a load factor of more than 70 per cent, it must also be assumed that the performance of the other 11 plants will improve. If the 11 other WWER-1000s are assumed to achieve a load factor of 75 per cent, which is the Ukrainian authorities' target, rather than 60 per cent, the extra output produced would exceed the likely output of K2/R4 and avoid the need to run a large amount of old, expensive plant. If this improvement could be relied upon, it would mean that the output of K2/R4 would effectively be replacing much lower cost plant than if a much lower assumption of performance was used and the case for K2/R4 would be correspondingly weaker.

The Panel therefore strongly recommended that the case for safety upgrades at the existing plants, which almost invariably would improve the reliability of these plants, be examined as a matter of priority to determine whether this would be a more productive use of the capital than investing in new capacity.

If it could only be assumed that K2/R4 would perform poorly, for example, an assumption of a load factor of 60 per cent, the costs of completing K2/R4 would be spread over fewer units of output, so increasing the cost of power from these plants. It would also be difficult to justify completing nuclear plants that were not expected to work well.

2A.4.2.1.3 Performance 1995 onwards: WWER-1000s

From the data that have become available since the Panel's report was written, there is some evidence that the performance of the WWER-1000 plants has begun to improve (see Table 2A.12), at least in Ukraine. Performance in Ukraine remains markedly better than that achieved in Russia and Bulgaria with plants of the same design. In 1997, nine of the 11 units in the Ukraine exceeded a load of 70 per cent. The data for 1998 must be interpreted with care as the period from January to the end of June is one when much of the annual maintenance and refuelling would not yet have been scheduled. The load factors achieved in this period are therefore likely to be somewhat better than those achieved over the year as a whole. In 1997, the average for January to June was 73.5 per cent compared to the annual average of 72 per cent. So if 1997 is a good guide, performance in 1998 will be similar to that achieved in 1997.

Table 2A.12: Ukraine Nuclear Power Plant Performance – 1990-98

	WWER-1000	RBMK-1000	WWER-440
1990	60.0	65.4	82.6
1991	62.7	54.4	77.3
1992	73.9	32.4	92.8
1993	64.9	71.7	71.4
1994	59.4	58.9	80.8
1995	59.2	66.4	81.6
1996	62.4	70.2	81.4
1997	71.9	50.1	78.1
1998 (to end June)	73.5	21.1	60.2

How the improvement since 1996 has been achieved and whether it will be sustainable remains to be seen.[38] In 1992, a similar level of performance was reached, but detailed examination of the records submitted to the IAEA shows this was accomplished largely by operating the plants at up to 10 per cent above their design rating. IAEA records show this policy had not been repeated up to the end of 1996 and examination of monthly data since then suggests that running at significantly above design capacity has not occurred in 1997 and 1998.

This improvement in availability should also be seen in the context of allegations made by the head of the Ukrainian safety authorities.[39] He accused plant management of systematically violating safety standards, for example by returning a unit to service before full safety checks had been carried out and by failing to replace worn out equipment.

By contrast with the apparent improvement in annual load factor, the performance at winter peak is less impressive and may even have declined, although the lack of data for two months in 1997 makes this difficult to establish (see Table 2A.13). There would appear to be no justification for increasing the assumption used in the Panel report that winter peak availability would be 85 per cent.

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[38] The Zaporozhe 6 unit is difficult to take into account. This plant went critical in October 1995, but was not declared commercial until September 1996. Since the period between first criticality and commercial operation involves testing, the plant is not operating to its full capability and performance is generally below the long-term average. However, because the plant has a full charge of fresh fuel, it is not necessary to take it down for refuelling during this period, increasing the performance. Performance before commercial operation is not therefore usually included in performance analyses and is not included in the following tables. The absence of a need to refuel in the pre-commercial period seems to have been more important at Zaporozhe 6 than the need for tests and, in 1996, Zaporozhe 6 achieved the best load factor (76.7) of any of the WWER-1000 s in Ukraine.

[39] 'Ukrainian standards attacked by domestic nuclear regulator', East European Energy Report, July 1998, p 25, Financial Times Energy, London.

Table 2A.13: Winter Availability of WWER-1000 Plants in Ukraine

	1994/95	1995/96	1996/97	1997/98	Mean
December	80.7	76.6	84.9	76.1	79.6
January	90.6	83.5	85.2	73.8	83.3
February	86.1	80.7	*	83.7	83.5
March	75.9	80.4	*	80.4	78.9
Mean	83.3	80.3	-	78.5	81.3

*Note: * No data was published for February and March 1997.*

The IAEA data give the opportunity to examine in detail what factors were important in determining the load factors achieved. In particular, it is possible to disaggregate the output not produced into three main categories, outage losses (these occur when the plant is not producing power at all), derating losses (these occur if the plant is licensed to operate at below the design level) and operating losses (these occur if the plant is producing power, but at less than the licensed rating). Derating losses have not occurred at the WWER-1000 s and so are not tabulated.

Detailed performance data show that the small improvement in 1996 (the latest year for which detailed records are available) over the previous years seems to be entirely due to reduced operating losses (see Table 2A.14). Careful investigation of the high level of operating losses that were apparent in 1993-95 showed that this was a seasonal factor primarily affecting the South Ukraine and Zaporozhe sites. It appeared that there were difficulties in operating the units on these sites at full rating during summer. It was not clear what the problem was, but the high temperature of the cooling water leading to output restrictions seemed the most plausible explanation, although the low level of electricity demand during summer nights may have made it difficult to use all the output available. The operating losses were lower in 1996 and examination of the monthly records on a plant by plant basis showed no evidence of any problems of running at full power in the summer that year.

Table 2A.14: Detailed Performance of Ukrainian WWER-1000s – 1993/96

	Load Factor	**Outage Losses**	**Operating Losses**	**Forced Outage Frequency**
1993	64.9	25.7	9.4	4.7
1994	59.4	29.6	11.0	4.0
1995	59.2	31.1	9.7	2.2
1996	62.4	31.3	6.3	3.1

Another issue that had contributed to reduced power output was safety concerns over sticking control rods (this might cause problems when it was required to shut-down the plant quickly). Operation at reduced power to reduce this risk was imposed while the source and solution to this problem were being determined. There is no evidence from the detailed records to show that this problem adversely affected performance from 1996 onwards. The forced outage frequency for 1996 was poorer than for 1995, although better than in four out of the five years before then and, by international standards, is respectable enough.

The distribution of the detailed causes of outage for 1996 by category is very similar to those for 1995 (see Table 2A.15). The exception is the absence of testing, which was primarily associated with the control rod sticking problem. Maintenance and repair outages continue to be longer than in previous years.

Table 2A.15: Causes of Outage in Ukrainian WWER-1000s – 1993/96

Equivalent hours lost per 6000 hours on line	A	B	C	D	Others
1993	164	104	1521	1	180
1994	30	12	1963	63	115
1995	29	136	2012	111	51
1996	36	112	2033	0	241

Notes: Includes only outage categories which in any one year exceed 100 hours equivalent
A = Equipment failure in reactor control system and instrumentation
B = Equipment failure in the steam turbine or the generator
C = Refuelling, maintenance and repair
D = Testing of plant systems and components

2A.4.2.1.4 Performance 1995 onwards: other plants

The remaining operational unit at Chernobyl, unit 3, was shut-down in May 1997 for maintenance and repairs and returned to service on May 14 1998. During the repairs, it was planned to replace 10 per cent of the fuel channels. The fuel channels have a design life of about 15 years (the age Chernobyl 3 had reached), at which point the plant must either be re-channelled or shut down. Full replacement of the fuel channels would cost several hundred million dollars and, at unit 1, it was the prohibitive cost of this operation that led to the decision to close the plant permanently in 1996. The reactor at unit 2, at which the turbine hall was destroyed by fire in 1991, still has a few years operating life left in the fuel channels and one option the Ukraine authorities have continued to canvass would be to connect the reactor at unit 2 to the turbine of the retired unit 1. There has even been official consideration of replacing the turbine at unit 1 and retubing the plant to allow all three surviving reactors at Chernobyl to operate well into the next century.

The repairs at unit 3 represented the first part of a project to allow it to operate for at least another decade and were expected to be completed in October 1997. During this outage, cracks in a number of welds in important piping were found and repairs continued until May 1998.

The performance of the two WWER-440 units at Rovno, like that of almost all plants of this design wherever installed, remains consistently good.

2A.4.2.1.5 Conclusions

There is evidence of an improvement in the operating performance of Ukrainian WWER-1000 plants over the past 18 months. However, it is not yet possible to determine what factors contributed to this improvement and whether it can be sustained in the long term. The average annual performance in the years 1993-96 lay in the range 59-65 per cent. Given the improvement in performance over the last 18 months, it may be appropriate to assume somewhat higher performance than the Panel did in its original report from 60 per cent to 65 per cent for the existing plants. However, to the extent that this improvement has come from the improved management that was already factored in for K2/R4, there is no reason to increase the assumed performance of K2/R4 above the 67.5 per cent used in the Panel's report. On winter peak availability, the Panel assumed 85 per cent for existing plants and 90 per cent for K2/R4 and there is no strong evidence to assume better performance.

2A.4.2.2 Experience in completing Mochovce and Temelin and of safety upgrades at Kozloduy

The section summarises experience with the projects to complete part-built nuclear power plants at Temelin in the Czech Republic and Mochovce in the Slovak Republic, and the attempts to launch a programme of safety upgrades at the Kozloduy plant in Bulgaria. These projects provide important if not exact parallels with the K2/R4 project and the possible safety upgrades at the 11 plants of the same design as K2/R4 already operating in Ukraine.

A common factor applying to all three projects is that the original studies and the existing construction work were carried out largely under the control of the Soviet authorities and enterprises. Doubts have been raised about the quality of this work and of the supporting studies, for example on seismic conditions at the site.

An important difference, though difficult to quantify, is in the nuclear skill base in the three countries involved. All three countries have had to build independent capabilities since the break-up of the Soviet Bloc in areas, e.g., safety regulation, where they had previously relied on Soviet capabilities. Building a strong, independent regulatory authority cannot be quickly or easily done. Due to lack of financial resources and other factors, Ukraine's Nuclear Safety Authority is still not an independent, effective regulatory body.[40]

The former Czechoslovakia was the one country in the Soviet Bloc that had some independent capability in nuclear engineering. The Skoda company, based in the Czech part of the country, has a long history in power engineering and was able to manufacture a significant proportion of nuclear equipment for the plants. Czechoslovakia also had some capability in reactor design, having completed a prototype plant (albeit unsuccessful) of its own unique design. Nothing comparable to the Skoda facility is available in Ukraine.

2A.4.2.2.1 Completion of part-built plants

Projects to complete part-built nuclear power plants at which a major discontinuity has occurred, such as a halt in the construction process for a significant period, a change in the major contractors, or major modifications to the design, are very unusual. It is therefore important in evaluating the proposal to complete K2/R4 to examine relevant experience from which lessons can be drawn.

The main discontinuity with the K2/R4 project is the halt in construction from 1990 onwards. If Khmelnitsky 2 and Rovno 4 are completed sequentially, this could mean that work at the Rovno 4 plant will have been halted for more than 13 years. This raises particular issues about the measures taken to ensure that part-completed work and equipment already installed, or on site awaiting installation, are maintained in good condition. There have also been questions raised about the extent to which checks need now to be made to ensure equipment and construction work are of a sufficient standard.[41]

It is not clear yet who the contractors for the K2/R4 completion will be. But if completion is funded by the West, it is not likely to be fully in the hands of Russian contractors, as was the case for the work carried out so far. Construction was so far advanced when it was halted – about 80 per cent – that major design modifications would be prohibitively expensive as they would require extensive reconstruction. The completion proposals include relatively minor upgrades to the existing design.

[40] R J Budnitz, N Steinberg (1998) 'Lessons learned from the first years of the multi-national safety assistance program for Soviet-designed reactors', paper presented to the American Nuclear Society, October 1998.

[41] International Atomic Energy Agency (1995) 'Report of an experts' mission to review the modernisation programme of Rovno NPP unit 4: 2-12 October 1995' TC Project RER/91035, IAEA, Vienna.

Temelin

The Temelin plant, owned by the Czech utility, CEZ, also involves two plants of the WWER-1000 design, but under construction on the same site. It was ordered in 1982 and the main construction work started in 1985. Construction work was slowed in 1990 after the break up of the Soviet Bloc and, in 1991, CEZ began studies into the measures which would be necessary to bring safety provisions up to current Western standards. Construction work on the site has however been continuous, unlike K2/R4, albeit at a very slow pace between 1990 and 1994, and storage and maintenance of already installed equipment and equipment delivered to the site awaiting installation have not been raised as a major issue.

The replacement of the instrumentation and control (I&C) systems marks the Temelin completion project out as very different to the completion of K2/R4. This was possible because construction was not so far advanced as K2/R4 when Western contractors became involved in 1993. Unit 1 was estimated to be about 60 per cent complete and unit 2, 40 per cent. This meant that design changes, more fundamental than possible at K2/R4, could be incorporated, and checks on the quality of existing work were easier to carry out. The aim was to achieve parity with Western standards of the 1990s. It is claimed that completion of K2/R4 will bring the plants up to Western safety standards, but closer examination of the wording shows that this refers to Western standards that prevailed when the plants were designed. This effectively means Western standards of the early 1970s. This has particular relevance to the I&C systems. Following the fire in 1975 at a US nuclear power plant, Browns Ferry, when three plants on the site were disabled by a fire in the common I&C system, it has become mandatory for all new nuclear power plants to have independent an I&C system for each individual unit, so a problem with one plant should not have major repercussions for another one.

In 1993, the Czech company, Skoda was selected as the main contractor at Temelin with Westinghouse as sub-contractor for supply of fuel and an I&C system to replace that supplied by the Russian contractors. Construction resumed in 1994. Operation of the first unit was then scheduled for 1996, although Westinghouse was hoping to be able to complete the plant earlier. The entire completion project was expected to cost 68 billion Czech Crowns (CZK), about US $ 2bn, of which only US $ 334m was contracted to Westinghouse.

When the contracts were finally signed, it was expected that the plant would be complete by late 1996 or early 1997. By February 1996, the completion cost estimate had increased to CZK76bn and the completion schedule could not be met. In February 1997, the completion date targets had slipped further, with unit 1 not expected to enter commercial service until autumn 1999 followed about 18 months later by unit 2, and the completion cost estimate had risen to CZK83 bn. An indication of the scale of the problems came in the Westinghouse annual report published in May 1997. This showed that Westinghouse was taking a charge in its accounts of US $ 50m to cover expected losses on the Temelin contract. The main problem appears to be the I&C system and huge quantities of already laid cables (estimated at 1100 km) which will have to be pulled and replaced to bring the safety levels up to the target level. Changes to the scope of the work had increased the contract value from US $ 334m to about US $ 500 m, but this by no means accounted for the full extent of the cost overruns.

By December 1997, the completion cost estimate had increased to CZK84.9 bn and completion was not expected until late 2000 for the first unit. This led the Czech government, which owns 67 per cent of CEZ shares, to become more directly involved in the project, monitoring progress on a two-monthly, rather than a six-monthly basis. Political changes – a caretaker government had been in power since mid-1997 – and the imminence of national elections in June 1998 limited the extent to which government could influence events. Nevertheless, in January 1998, all board members were removed at an emergency general meeting instigated by the government.

After re-negotiations with contractors, the estimated completion cost was revised up again to CZK98.6bn and unit 1 is not expected to enter commercial service until mid 2001, five years late. Government concern at these delays and the accompanying cost overruns has led to a proposal in July 1998 to appoint an international panel of experts to assess whether continuing to complete the plants was justified. Whether this proposal is carried out will depend on the attitude of the new government being formed after the June elections when its composition is finally negotiated.

The individual elements of this increase are of relevance to K2/R4. CEZ has given a breakdown of the increase in the Temelin budget from 1995 to 1998. In this period, excluding 'reserves' (contingency), the total project budget rose from CZK71.3 bn to CZK96.0 bn. Out of this increase of CZK24.7 bn, CZK5.7 bn was accounted for by inflation, so that cost increase in real terms over the period was 24.6 per cent (CZK19bn). Construction delays accounted for a further CZK5.2 bn, an increase of just under 7 per cent on the total project cost. However, the main element of the cost over-run, CZK13.7bn (17.8 per cent), derived from modifications to the project. It has been reported that there have been more than 4000 design changes since the re-start of construction. CEZ attributes the extra costs to four main parties:

- Westinghouse: CZK6.3 bn, of which CZK2.5 bn was due to a reduction in the value of the Crown against the US dollar;
- CEZ: CZK2.8 bn;
- SUJB (the nuclear safety regulatory body): CZK2.3 bn;
- Recommendations of international bodies (International Atomic Energy Agency and NUS): CZK1.9 bn.

Financial and Contractual Arrangements for Temelin

Financing arrangements were complicated, but were based on local sources backed up by guarantees from the US ExIm Bank and a Belgian government agency. The ExIm Bank of the USA, which is an export guarantee agency, gave preliminary approval to guarantee a contract to Westinghouse worth US $ 365 m in 1991. However, the process of reaching final agreement on financing was lengthy. This was mainly due to public opposition to the project in the USA, doubts within the banking community about its financial viability, issues of accident liability and a lengthy process of gaining safety approval from both the Czech and the US authorities. The US Nuclear Regulatory Commission (NRC) is required under US law to ensure that any work on foreign plants carried out by US contractors would meet US standards

In January 1994, ExIm Bank agreed in principle to guarantee a loan from an international consortium led by Citibank to Westinghouse for its part in the project. However, political difficulties continued and it was not until March 1994 that political approval for the decision to guarantee the US $ 334m loan was given. Repayments on this loan are scheduled to commence in 1999.

Delays to the completion of Temelin began to cause major practical and financial problems to CEZ in late 1997. By then there was speculation that the Czech Republic would need to begin to import power to replace that expected to come from Temelin in 1998/99. On the financial side, the first instalment on the loans was due for repayment in 1997 and ExIm Bank conditions required that the Westinghouse money be spent on unit 1 by December 1997 and on unit 2 by March 1998. By the end of 1997, less than US $ 200 m had been billed by Westinghouse, but Westinghouse had requested about US $ 100m for additional work that was required which was not in the original project scope.

The main element of the Westinghouse contract was the I&C system which originally accounted for US $ 220 m of the cost. Cost over-runs on this had led to provision in Westinghouse's 1997 accounts for US $ 49 m of extra costs arising from its work at Temelin. Westinghouse claimed the problem arose mainly because the scope of the work had increased and in June 1998, a re-negotiated contract was agreed between CEZ and Westinghouse to replace the fixed price contract with one based on 'time and materials' – essentially cost-plus – spent by Westinghouse, under the supervision of CEZ.

Mochovce

The Mochovce nuclear power plant in the Slovak Republic comprises four units of about 440 MW, each of the Soviet WWER-440/213 designs and is owned by Slovenske Elektrarne (SE). These plants have been under construction since the early 1980s, but work on them was essentially halted following the break-up of the Soviet Bloc in 1990. Construction on two of the units recommenced in 1996, at which time it was estimated that at unit 1, construction was 95 per cent complete and engineering 85 per cent complete, while at unit two, the completion estimates were 75 per cent for construction and 70 per cent for engineering.

The process of commissioning for the first unit began in August 1997. It was completed and went critical in June 1998, only a little later than the time expected in April 1996 when work was recommenced, and it is expected to enter commercial service at the end of the year. Unit 2 is expected to follow about a year later, a few months after the projected completion date. It has not yet been decided whether work on units 3 and 4, on which work was less advanced than units 1 and 2 (55 per cent of construction and 30 per cent of engineering), will be recommenced. In contrast to Temelin, where every effort has been made to bring safety standards up to the state-of-the-art, at Mochovce, a conscious decision was taken to minimise design changes.

The first unit was brought on line reasonably close to the time forecast, although this was only achieved at the expense of putting off some safety upgrades, not the highest priority ones, until the first refuelling outage. There was also considerable controversy at the time about how thoroughly safety checks on the existing work had been carried out, in particular, on the quality of the reactor pressure vessel. Closure of two old units of the WWER-440/230 design at Bohunice, one of the key incentives behind Western funding of the completion of the plants, has now been postponed. The original target in the West of closure by 2000 has been forgotten and modernisation work has been carried out by SE which SE argue would allow the plants to operate safely until at least 2010.

Financial and Contractual Arrangements for Mochovce

From 1993 onwards, discussions were taking place on the completion of the Mochovce plants. The project was expected to be led by the French utility EDF and the German utilities, Bayernwerk and Preussenelektra and would have involved Siemens and Framatome. The main financiers were expected to be the EBRD and the European Union. This caused a great deal of hostility, particularly towards EBRD, both on the expected safety of the plant and on the economic case for completion. In 1995, discussions between the EBRD and the Slovak authorities on financing the completion of the plants, then estimated to cost DM1.45 bn (US $ 950 m), finally broke down. The Slovak authorities were unwilling to comply with the conditions which the EBRD put on the loan. In particular, EBRD requested that electricity prices be increased by 25 per cent and that two older nuclear plants at Bohunice be closed by 2000 because of concerns about their safety.

As a result, the Slovak government withdrew its request for finance in September 1995 and switched to a proposal put forward by Skoda and financed from Czech, Russian and Western banks. It was claimed this would achieve comparable safety standards to the EDF proposals but would cost a third less, DM1bn. By April 1996, when contracts were finally signed, the completion cost estimate had increased somewhat to DM1.3bn (about US $ 860 m or 27.9 bn Slovak crowns). Virtually all the loans (98 per cent) were backed by the Slovak government.

Like Temelin, the project is led by Skoda, but the Western contractors involved are West European and include the French utility, EDF, and Eucom, a consortium of Framatome and Siemens. Eucom's contract was worth US $ 100m and covered safety upgrade work at the two units (see Table 2A.16).

Table 2A.16: The Mochovce Completion Project

Financier	Loan (US $ m)	Contractors
Komercni Banka (Czech)	200	Skoda (Czech)
Ceska Sporitelna (Czech)	65	Energoprojekt Prague (Czech)
Kreditanstalt fur Wiederaufbau (Germ)	130	Atomenergoprojekt (Russia)
Societe General (France)	42	Zarubezhatomenergostroy (Russia)
VUB (Slovak)	95	Hydrostav (Slovak)
Slovenska Sporitelna (Slovak)	195	EZ Elektrosystemy (Slovak)
Russia (equipment & assistance)	80	VUJE (Slovak)
Russia (fuel)	70	EDF (France) Siemens/Framatome consortium

2A.4.2.2.2 Safety Upgrades at Kozloduy

One of the priorities in Western policy towards the nuclear sector in the FSU and Eastern Europe has been the early closure of reactor designs deemed unsafe, in particular, the Chernobyl design, the RBMK, and the first generation design of WWER plants, the WWER-440/230. Another priority has been the programme to upgrade safety at WWER-1000 plants, replacing some of the original Russian equipment with better performing products and adding further safety systems. This policy is particularly relevant to Bulgaria which has four units of the WWER-440/230 design and two of the WWER-1000 design, all installed at the Kozloduy site. It has also gained particular prominence following an 'ASSET' inspection of Kozloduy in 1991 by an IAEA sponsored team, when the plants were found to be in an alarmingly poor state of repair.[42]

Despite poor performance at the WWER-1000s and lengthy shut-downs at the WWER-440s for short-term safety upgrades, nuclear power accounts for almost half Bulgaria's electricity demand. The poor performance of the Bulgarian economy and its reliance on nuclear power has led to a belief that Western aid, through the EBRD's NSA will be needed if Bulgaria is to be able to close at least the two oldest WWER-440s. The situation has some parallels with Ukraine because closure of the WWER-440s has been made conditional by Bulgaria on the availability of replacement power. Target dates for closure of Kozloduy have been missed because replacement power projects, including upgrading the WWER-1000s, but also fossil fuel plant refurbishment and building a pumped storage hydro plant have not been completed in time.

Since 1993, there has been a recognition of the need to upgrade the WWER-1000s.[43] It was expected that, by replacing unreliable equipment with better kit, the reliability of the plants would be improved and the extra output would partially compensate for the closure of the WWER-440s. For example, in Bulgaria, if the load factor at the two WWER-1000s could be improved from the recent average of 50-55 per cent to 75 per cent, the extra output would be nearly equivalent to two of the older WWER-440 plants. From the point of view of Western nuclear vendors, this has been an extremely important project as it would act as a demonstration of what could be achieved in the other 18 operating plants of the WWER-1000 design in Eastern Europe and the FSU, all of which are potentially candidates for upgrading.

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[42] International Atomic Energy Agency (1991) 'Kozloduy safety review mission' IAEA-WWER-RD-033, IAEA, Vienna.

[43] International Atomic Energy Agency (1996) 'Safety issues and their ranking for WWER-1000 model 320 nuclear power plants' IAEA-EBP-WWER-05, IAEA, Vienna.

In August 1996, when the Bulgarian utility, NEK, put out a call for bids, valued at about US $ 250 m, for upgrades to Kozloduy 5 and 6, the major active nuclear vendors in Europe and USA, notably Siemens and Westinghouse, were formulating proposals for upgrading WWER-1000 s. The programme was derived from a generic study for WWER-1000s carried out by EDF and a Russian company, MOHT. It was expected that these would be funded to a large extent by Western export credit agencies and would be completed by 1998. The long-term nature of the improvements meant the projects were deemed to be outside the scope of the EBRD Nuclear Safety Account.

However, funding and agreeing on the details of the upgrades have proved problematic. In January 1997, it was announced that consortium of Siemens, Framatome and Atomenergo-export (Russia), European Consortium Kozloduy (ECK) had been chosen by the Bulgarian authorities to carry out a large element of the work valued at about US $ 200m. It was expected this would be largely financed by a Euratom loan covering 85 per cent of the cost. Westinghouse was chosen for a smaller project, valued at about US $ 40m, to be fully financed by the ExIm Bank. By the end of 1997, finance had still not been arranged and the two chosen companies, the ECK consortium and Westinghouse, were still negotiating with NEK. A NEK representative described the cost estimates as 'very, very preliminary'.44 The total cost was dependent on the results of a preliminary engineering phase, expected to account for 30 per cent of the total cost (by then estimated at ECU 270 m (US $ 300 m)) and lasting 18 months, in which specifications for the equipment would be prepared.

Earlier, it had been hoped that upgrades would be completed in only a couple of years, by the end of 1998, at which time Kozloduy 1-4 would be retired. By 1997, it was expected the modernisation work at units 5 and 6 would take four years after a preliminary engineering phase lasting a year and would be accommodated in normal maintenance outages. Short-term safety upgrades agreed in 1993 to allow units 1-4 to continue in service until 1998, expected to take 18 months, were not completed until 1998, by which time, the Bulgarian authorities were arguing that more detailed studies at Kozloduy and two similar units at Bohunice in the Slovak Republic showed that safety upgrades would allow these plants to continue in service safely until at least 2010. Siemens is negotiating to carry out further modernisation at these units.

In January 1998, a small contract (financed under the EU Phare programme) was finally let to a British/Spanish consortium to cover management of the safety upgrade programme. The contracts for the preliminary engineering phase work were signed with Westinghouse in January 1998 and with ECK in March 1998. It is planned that the main contracts for the actual modernisation work will be signed in mid-1999 to allow work to begin at the end of that year. NEK financed 50 per cent of the preliminary ECK contract (this contract was valued at US $ 29 m) with the balance coming from Russian and German export financing organisations. NEK financed the preliminary Westinghouse work (worth US $ 6 m) in full.

2A.4.2.2.3 Lessons

Several lessons emerge from the Temelin, Mochovce and Kozloduy projects. The first is that projects such as these are extremely difficult to fund, especially by IFIs. Even for the Kozloduy project, which probably involves the lowest financial risk of the three, it has taken two years to fund a preliminary phase and this was possible only because the Bulgarian utility bore most of the burden. As more detail on the huge time and cost over-runs at Temelin become available, the perceived risk of financing such projects will increase and funding will become more difficult and will attra t

A second lesson is that utilities are extremely reluctant to shut down operating nuclear power plant deemed unsafe, especially where the plants have a good record of reliability. The up-

[44] P Marshall 'Kozloduy shutdown evaporates as safety improves, alternatives fade' Nucleonics Week, 11 December 1997, pp 1, 12, 13.

grading of Kozloduy 5 & 6 and the completion of Mochovce 1 & 2 were expected to allow early closure of plants (Kozloduy 1-4 and Bohunice 1 & 2) of a design which the West has characterised as unsafe. The utilities that own these plants appear to view them as a source of extra revenue, perhaps through the export of surplus power not needed for the national system. These utilities are in serious financial difficulties and can ill afford to pass over the opportunity to earn extra income, especially in Western currency.

The Temelin and Mochovce projects represent alternative ways to complete part-built plants. In the Mochovce case this involved building the plant as originally designed and in the Temelin case upgrading it as fully as possible to current standards. The choices made may have at least as much to do with the degree of completion and the technology at the two sites, as with a basic difference in philosophy. Construction work was far advanced at the Mochovce plant, in the case of unit 1, at least 90 per cent, so any design changes would have been expensive as they would have required existing work to be ripped out. The basic design, the WWER-440, has invariably proved a reliable source of power in all operating plants and the particular model, the WWER-440/213, has few safety issues outstanding against it. The completion of Mochovce has proved much less problematic, staying much closer to the forecast completion date than Temelin. However, this has not been achieved without some cost and time over-runs which have caused the owner, Slovenske Elektrarne, significant financial problems.

By contrast, the Temelin units were at a much earlier stage in construction, in the case of unit 2, 40 per cent, so design changes – more necessary in view of the mediocre operating record of the WWER-1000 design – required much less disturbance of the existing work. Although blame for the huge over-runs in time and cost at Temelin cannot be apportioned between participants, the Temelin experience provides strong evidence that completing a plant with an extensive requirement for design changes is economically a very risky project.

The characteristics of the K2/R4 completion proposal lie somewhere between the Mochovce and Temelin cases. The degree of completion is much closer to Mochovce, making an extensive programme of safety upgrades difficult. However, K2/R4 use the Temelin technology, which has a much poorer record of reliability and therefore a much greater apparent need for improvements to existing equipment. There is also the added complication of the serious reservations which an IAEA inspection team expressed on the quality of work that has been carried out so far and the deficiencies in the way in which the site has been maintained during the eight year period in which no work has been carried out. This can only increase the uncertainty surrounding the estimates of completion time and cost.

Experience of modernising Kozloduy 5 and 6 is still at an early stage, but is highly relevant to Ukraine. G7 policy would imply a similar programme of safety upgrades to the 11 operating WWER-1000 s in Ukraine costing nearly US $ 2 bn, as well as the two part-built plants, K2/R4. The K2/R4 upgrades are not expected to be completed until the first maintenance period. However, it is clear from the slow progress at Kozloduy and the splitting of the project into a preliminary and a main section, that the programme of upgrades is still far from defined and the costs are equally uncertain.

2A.5 Conclusions

Despite the attractiveness of closing Chernobyl, under the Memorandum of Understanding (MOU) signed in December 1995, the apparent appeal of doing so by completing Khmelnitsky 2 and Rovno 4 (K2/R4) falls apart under close examination of Ukraine's situation and of the K2/R4 project itself.

We conclude from the evidence in this report that the Stone & Webster (S&W) report to the European Bank for Reconstruction and Development (EBRD) does not provide convincing evidence that completing K2/R4 will be 'least cost'. This is due both to the total reliance on computer modelling in a situation in which the pervasive uncertainties make that inappropriate, and the assumptions made for key variables which bias the modelling results towards the completion of K2/R4. Basing a decision on K2/R4 on these modelling results would therefore be a high risk strategy. We conclude that K2/R4 remain uneconomic for Ukraine. They will produce a national electric bill and electric prices higher than other feasible choices. Especially given Ukraine's current economic situation, the country cannot afford this result.

The S&W report therefore gives no credible reason to alter the conclusions of the original EBRD panel of international experts (see Appendix for the Panel's conclusions of February 1997). Studies exhibiting the biases and flaws of the S&W report are a serious matter, especially in a country as urgently in need of effective assistance as is Ukraine. Similar errors in least cost analysis technique have led to the waste of billions of dollars in the US on plants once considered least cost and necessary, only to be cancelled a few years later without any adverse reliability or economic consequences. Ukraine cannot afford to travel this road.

The Ukrainian electricity system certainly needs money spent on it, but not for new generating capacity. The economic recession has been so deep that electricity demand has fallen by about 50 per cent in the last eight years leaving Ukraine with a large surplus of capacity, but no money to maintain either the generating plant or the transmission and distribution system. As a result, Ukraine has more than enough plant to meet demands but, because there is no money to buy spares and fuel, and carry out proper maintenance, the reliability of the system is poor and deteriorating, and may prove a barrier to economic recovery. Diverting the capital that is available into K2/R4 will only make things worse.

Even if economic recovery begins sooner rather than later, the chances of Ukraine needing new capacity are small. The electricity demands that applied in the Soviet era, which made Ukraine among the most electricity intensive countries in the world, were based on heavy industries providing basic materials, usually using out-dated inefficient technologies. Ukraine's recovery is likely to depend on the least efficient industrial plants being closed down and the better ones being modernised. New manufacturing and service industries will tend to use less electricity, especially base-load power.

Completing K2/R4 is not a quick and easy option. Costs and lead-times would be at serious risk of over-running from a number of causes detailed in our report. For example, doubts by authoritative bodies have been raised about the quality of the work done and the conditions under which the plants have been stored. If detailed surveys of the condition of the plant reveal the need for a large amount of remedial and rebuilding work, this will raise costs and delay completion. The Temelin and Mochovce experience shows the problems of trying to complete and upgrade the safety systems of part-built, Soviet-designed nuclear reactors.

In this light, completing K2/R4 is likely to prove a costly and risky diversion away from addressing the urgent problems that the Ukrainian electricity sector is facing. There is unlikely to be any need in the foreseeable future for the output of K2/R4, especially if the reliability of the existing nuclear plants improves.

The MOU seemed to offer a sure way to close Chernobyl by offering grants to cover the direct costs of cleaning up the site and guaranteeing US $ 1.8 bn of much-needed Western loans for investment in projects in the Ukraine electric power sector. The MOU was right in addressing Ukraine's urgent need for capital, but unfortunate in appearing to tie much of the capital to K2/R4. Abandoning K2/R4 now would clear the way for the flow of investments to much better projects, of which there are plenty.

APPENDIX:
Conclusions od the International Panel, February 1997[45]

182. The situation in Ukraine is one of economic crisis and social hardship. The hardship is worse during the winter largely because of the limited funds which have been available to buy the fuels necessary to keep the lights on and to keep warm. Although our report is about longer-term priorities for the energy sector, we emphasise the need for effective short-term assistance to ensure the basic necessities of life for the Ukrainian people are met – particularly over the cold Ukrainian winter.

183. The main questions we have to address are whether completing K2/R4 is economic and whether these two 1000 MW reactors form part of a 'least-cost' plan for the development of Ukraine's energy sector. We conclude that K2/R4 are not economic. Completing these reactors would not represent the most productive use of US $ 1bn or more of EBRD/EU funds at this time. We have been given no reason to think that the economics of the two plants differ by enough to justify going forward with one but not the other. It is, of course, possible that benefits such as transmission system support provide some basis for differentiating further among the two units, but we consider it highly unlikely that these benefits would tip the balance in favour of completion of either unit.

184. Central to this conclusion are the following points:

- Electricity demand has been so reduced by the still worsening economic situation that there is a large capacity surplus which, in our judgement, may well last until 2010. In particular there is no need for additional base load capacity now nor especially when industrial restructuring away from the heavy industrial plant gathers pace as it probably will when economic recovery takes place. Installing surplus generating capacity would use up limited borrowing authority for a purpose not needed and make it more difficult to achieve the economic efficiency objectives behind the Government's market-based reforms in the energy sector.
- We have little confidence in any of the various elements of the estimated costs for K2/R4 (of completion, operation and maintenance, fuel cycle, waste disposal and decommissioning). This basic lack of confidence in the cost estimates makes K2/R4 a high risk investment, especially as we have no reason to think that the generating costs of K2/R4 (including an appropriate rate of return on capital) will be less than the avoidable cost of existing fossil fuel plant.
- The need for safety upgrades in the existing WWER-1000 stations is pressing. We understand that as well as increasing safety, these upgrades could increase reliability and therefore the output of these plants. Every 5 per cent availability increase would add 650 MW. If this proves to be correct, the extra output of the existing nuclear stations would make K2/R4 even more unnecessary. However, if the safety upgrades did not increase output, K2/R4 would be no more reliable than the existing WWERs with load factors around 60 per cent.
- Even in relation to winter peak demand, Ukraine now has large surplus generating capacity. The power shortages cannot therefore be due to insufficient generating capacity. The power plant rehabilitation programme and the loans for working capital purposes currently offer the best option for eliminating the causes of the power shortages, provided that consumers resume paying their electricity bills.
- Low energy efficiency in final uses and conversion processes, and high energy losses in electricity transmission and gas pipelines and district heating schemes, appear to present an opportunity to improve overall productivity, reduce energy demand and reduce environmental impacts and increase effective electricity supply capacity – all at relatively low cost.

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[45] The Panel's report also contained a 'Note of Dissent' from Professor Lennart Hjalmarsson.

185. Ukraine has decided to operate its future electric power system on a market-oriented and privatised basis. A fundamental principle of such a system is that neither the customer nor the government should be expected to bear the risk of incorrect power supply decisions. This is especially true when, as in Ukraine, many of the largest electricity users are in precarious economic condition and cannot afford a course of action that will saddle them with higher-than-necessary energy bills in the future. Such mistakes are a likely road to increased bankruptcies and job losses.

186. When a market system is fully operational, it would seek bids on the optimal ways to meet future Ukraine power needs without Chernobyl. Such bids would come in the form of proposals to save energy as well as to produce it. Major energy saving proposals might well be part of overall industrial modernisation plans. The bidders would have to stand behind their proposals in many important respects. Risk of non-performance, of equipment failure, and of delay would largely be borne by these developers in the first instance, not by the customers or the government in Ukraine, nor by EBRD. Such a system is not in place in Ukraine now, but EBRD would do well to urge the replication of its features to the greatest possible extent – both in ascertaining the available projects and in insisting on a preference to developers for projects which minimise risk to Ukraine and to EBRD.

187. As Ukrainian consumers increasingly pay their electricity bills in full and on time, and as the prices charged increasingly cover the full costs of electricity generation, transmission, distribution and supply, efficient electricity use will be encouraged and electricity growth will be lower than the growth in GDP. Another factor tending to reduce the extremely high energy intensity is that growth will probably occur in the light, 'hi-tech', and service industries as opposed to the old heavy industries which are most likely to be progressively run down or modernised, in the latter case becoming more energy efficient.

188. Even when Chernobyl is completely shut down, it is highly unlikely that more base load capacity will be needed before 2010. Even if there were need for new plant in this period, it would be for new or refurbished load following plant, not base load plant. Meanwhile, provided that all consumers resume paying their bills and electricity prices cover full costs on a continuing basis, electric utilities will have the money to buy sufficient fuel and spare parts. We also expect that when industrial complexes are renovated, the existing 'heat only' district heating plants and high-efficiency cogeneration (CHP) plants will provide power and steam/hot water economically, further reducing the need for new central generating capacity.

189. We are aware of the concern of the authorities in Ukraine that if economic recovery occurs and K2/R4 are not completed, then recovery could be slowed or halted by insufficient generating capacity. For reasons already given, we think this is extremely unlikely. But if during the next 13 years the need did arise for new plant, the most economic response would be to obtain the maximum cost-effective energy savings and/or interruptible loads from the large industrial customers and, if necessary, build new generating capacity with short planning and construction lead times. Combined cycle gas turbine plant – with an overall lead time of under three years, high thermal efficiency, very low atmospheric emissions, ability to follow the load, and the availability of manufacturers' reliability guarantees – would be an obvious option. The gas savings, by modernising the compressors in the gas pipeline system and the measures to reduce gas consumption in power generation, would allow gas to be supplied to a large amount of combined cycle plant without being an extra burden on the balance of payments.

Alternatives

190. Although we were asked to assess whether completing K2/R4 would be economic, we recognise there are important wider considerations for both the G-7 and for Ukraine. Given these wider considerations, the Panel has considered, from the documentary evidence available, various types of project in the energy sector which we think are likely to form part of a least cost development programme for the Ukraine energy sector. We have not been able to assess the economics of these projects in detail nor determine the precise allocation of funds to them. We recommend that Ukrainians should be centrally involved in selecting the projects to be funded and that the full amount under the Memorandum of Understanding should be earmarked for such projects because of the urgent need to close Chernobyl and fund a long-term programme which is acceptable to Ukraine. For some of the projects grant assistance may be more appropriate than loans.

191. In our opinion, the following options are likely to prove more economic investments than completing K2/R4 and we recommend that they should be evaluated:

(i) Stopping the power shortages. Loans for buying coal and equipment spares have recently been agreed by the World Bank and EBRD and these will do much to reduce the misery of routine electricity shortages. We recommend further assistance if the existing loans are not sufficient, especially as the expected return on the existing loans is very high (38 per cent a year according to the World Bank). Consideration should also be given to accelerating the plant rehabilitation programme.

(ii) Nuclear safety upgrades. Although we recognise that there are difficulties, it is important that safety upgrades are carried out at all existing WWER-1000 nuclear plants to bring them up to modern standards in the Western countries. A major risk for the Ukrainian people is that if anything happened to one WWER-1000 which necessitated the closure or derating of all WWER-1000 s, the economic cost could be immense (especially if there were no way of supplying base load demand until the WWER s were replaced with some other type of capacity). Yet the safety upgrade programme appears not to have started, which may be due to the lack of technical solutions and/or lack of money. This programme should be carried out as soon as practical and funded by the West if that is necessary to avoid long delay and to achieve safety standards which would be acceptable in the West.

(iii) Transmission line upgrades. There are constraints on the transmission and distribution system in Ukraine which was designed as an integral part of the huge grid linking the various parts of the former Soviet Union. Investment to reduce the high transmission and distribution losses and to remove the constraints which reportedly limit the operation of some nuclear plants is almost certainly a least-cost option and should be evaluated.

iv) Modernising basic industries such as steel and food processing. Large energy savings are available in the industrial sector. The problem in obtaining them is often the difficulty of picking the plants which will survive the industrial restructuring which is likely sooner or later to take place. Some industries such as food processing will almost certainly survive. Industries with comparatively high energy costs such as steel are more likely to survive if they are modernised to incorporate energy efficient processes. Significant energy savings are possible if financing were available. We understand that loan guarantees would be particularly helpful for this type of approach in the industrial sector.

(v) Energy efficiency schemes in other sectors. The Ukrainian authorities now accept that over 40 per cent of total energy consumption could in principle be saved cost effectively. The Government has established an energy efficiency fund and a Commission to administer it. If capital were available, they could take bids and ensure the funds were invested in projects with the most benefits, including saving of imported natural gas. Sectoral studies in Ukraine have been conducted by both US and European consultants and confirm the large cost-effective potential for energy savings. We suggest that three types of energy saving schemes would be most appropriate, all focused on 'infrastructure' projects in cities accounting for a large proportion of total energy consumed in the household, commercial and administrative sectors. They provide major opportunities for low-risk 'infrastructure' energy saving through the introduction of international best practice techniques which can then be replicated many times. The fact that these energy using facilities tend to be municipally or otherwise publicly owned will make the administration far easier than having to identify and then deal with numerous individual or corporate owners. Installations and equipment in Ukraine (as in other parts of the former Soviet Union) are often of low quality. Rehabilitating them creates a large number of jobs where they are most needed. We envisage two main types of project under this heading: firstly, the modernisation of district heating plants and heat distribution lines; and secondly, energy saving schemes aimed at municipal or other public sector buildings including hospitals, offices, street lighting and pumping of water, heat and sewage.

(vi) Renewable energy. Ukraine has a large wind resource and has made a start in wind power generation; it also has potential for biomass. Although these sources will not make a large contribution for some time and the extent of their economic deployment is uncertain, the externality considerations discussed earlier favour taking an active interest in their development opportunities.

192 Clearly, none of these projects could by itself completely replace Chernobyl's capacity. However, oft-repeated Western experience has been that when nuclear plants have been cancelled or delayed for many years, the replacement has come (almost always at lower cost) not from one large alternative project but from the sum of many smaller undertakings and from energy efficiency.

193. The above suggestions represent more of a general strategy than a detailed plan. With a successful restructuring of the electricity sector and liberalisation of energy markets, the choice of investment projects in the electricity sector will be decided according to what is acceptable to private investors, as opposed to the least cost planning methodology. This transition will be sooner and smoother if major capital resources are not tied up in large-scale, irreversible investment projects which are not needed.

193. Although there seems no reason why Western funding in the context of the closure of Chernobyl should be limited to the energy sector, there will be no shortage of energy investment projects worth funding provided that prices cover costs and bills are paid. We have suggested above several types of project which are good candidates for support, subject to detailed further examination. In the meantime we believe it would be desirable to extend the World Bank and EBRD approach of lending money for working capital purposes. Such expenditures can have a large economic benefit for Ukraine, partly because they deal directly with the problem of power shortages and are subject to much less uncertainty than the investment projects we have mainly had to consider.

194. Finally, we frequently heard that "there is no time to consider alternative funding possibilities in Ukraine if Chernobyl is to be closed" in 2000. The excess of generating capacity in Ukraine is now so large that there is, in our view, ample time to give full consideration to the alternatives which we have suggested. However, no doubt should be left in Ukrainian minds of the intention to provide the funds specified in the Memorandum of Understanding.