LEAST-COST ELECTRIC POWER SYSTEM DEVELOPMENT ANALYSIS
For
European Bank for Reconstruction and Development

UKRAINE
Completion of
Khmelnitsky 2 and Rovno 4
Nuclear Power Generators
Economic Due Diligence

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Executive Summary

This analysis was undertaken on behalf of the European Bank for Reconstruction and Development as part of the economic due diligence on completion of the two Ukrainian nuclear power generating units Khmelnitsky 2 ("K2") and Rovno 4 ("R4"), which are already about 80% built.

The analysis determines whether the completion of K2 and R4 by 2002 is likely to form part of the least-cost development program for meeting demand on the Ukrainian power system over the long term ("least-cost"). Costs are expressed in economic terms, that is in constant 1997 prices excluding Ukrainian direct taxes and interest during construction. They comprise the construction costs of new power generating plant, the rehabilitation costs of existing power plant, decommissioning costs, and the operating costs of both existing and new plant (including fuel and waste disposal costs). Each cost is discounted to present (1997) values at 10% from the time that it is incurred.

The completion of K2 and R4 is evaluated as a component of an integrated program of investments over a long period, taken to be between 1998 and 2010, rather than as an isolated investment. The analysis considers investments in other forms of power supply capacity - both rehabilitation and construction - besides K2 and R4, as well as in measures that modify the demand of electricity users. The least-cost program is identified as the sequence of investments selected from these options that result in system demand being met at the lowest total cost in present value terms. The analysis was performed with the widely accepted EGEAS power planning model.

Assumptions

The analysis requires extensive data about the performance of existing power plants, which have a combined capacity of about 50,000 MW, and of options for developing the power system. A considerable effort has been made to gather reliable data, firstly from previous studies conducted in the last five years. Subsequently, a week-long review of the required data was carried out among interested parties at a meeting in Kiev, which resulted in a set of data that has been agreed to represent the Ukrainian power system reasonably well.

The approach used for the analysis specifically takes into account the significant uncertainty about future power demand, construction costs and fossil fuel costs in

Ukraine. The forecast or estimate of each of these key planning variables is thus expressed in terms of a range of values, rather than as a single value. This range is expressed in three values - low, middle and high - and each of these values is assigned the following relative probability of occurrence:

- for forecasts of power demand - 50% for the middle forecast of 28% increase between 1997 and 2010, and 25% each for the low forecast and high forecast;
- for fossil fuel prices - 50% for the middle forecast (gas at US$2.65/GJ, heavy fuel oil US$2.82/GJ, raw coal US$1.50/GJ, all delivered to power plant), and 25% each for the low forecast and high forecast;
- for costs of completing K2 and R4 as a single project - 40% for the middle estimate of US$ 1,181 million, 34% for the low estimate of US$ 984 million, and 26% for the high estimate of US$ 1,582 million.

For a given planning scenario, one of each set of the three values is selected for the key planning variables - power demand, completion cost for K2 and R4, and fossil fuel prices, producing a total of 27 scenarios for analysis.

The analysis assumed that Chernobyl Nuclear Power Station will be permanently closed by the year 2000 in accordance with the Memorandum of Understanding between Government of Ukraine and the G-7 of 20 December 1995.

Sensitivity analysis

In the base case planning scenario, in which the planning variables take their middle values, completion of both K2 and R4 in 2002 is part of the least-cost program.

The following sensitivity cases were carried out to show whether the completion of K2 and R4 in 2002 remains least-cost under a substantial change in the value of each of the key planning variables from its middle value. These tests assume that the other variables keep their middle values. The magnitude of the key variable changes and the corresponding results are summarized below:

- *The break-even economic cost of completing both K2 and R4* above which the least-cost timing for completion is later than 2002; this cost is approximately $1490 million, which is 26% higher than the "expected" middle value for joint completion cost.
- *a major contraction of Ukrainian electricity consumption.* (i) The system load is assumed to stay at the lowest level of the low load forecast, 154,800 GWh, instead of rising to 223,500 GWh by 2010; in this case K2 is selected in 2002 as part of the least-cost program, while R4 is not selected. (ii) The system load is assumed to drop by 17% from the 1997 level to 145,000 GWh in 2000, and from that point the load is assumed to grow at the same rate (4% per year) as in the low load forecast; in this case, the least-cost program includes completion of K2 in 2002 and R4 in 2005.
- *The cost of gas falls from the present level* of $2.65/GJ to a level that displaces the least-cost timing for completing K2 and R4 from 2002. Under a 28% fall in gas cost to $1.92/GJ, K2 is least-cost in 2002 and R4 is least-cost in 2004. Under a 32% fall in

gas cost to $1.80/GJ, K2 is least-cost in 2003 and R4 is least-cost in 2005.

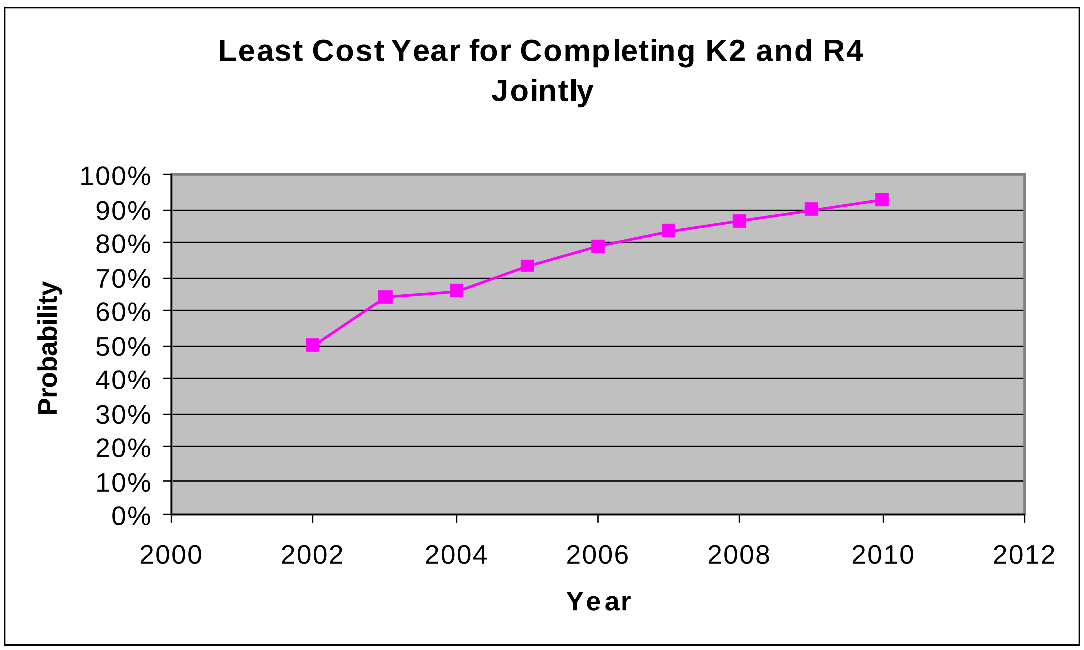
- *The opportunity cost of capital to Ukraine (the discount rate) is higher than 10%.* At 13%, K2 is least-cost in 2003 and R4 is least-cost in 2005. At 16%, K2 is least-cost in 2006 and R4 is least-cost in 2009. At 20%, K2 is least-cost in 2007 and R4 is least-cost in 2009.

Probabilities of being least-cost

Because of the uncertainty about future values for the planning parameters, however, the base case scenario has only a relatively small probability of occurrence, equal to 10% (0.5*0.4*0.5 = 0.10). The objective of the analysis is thus to determine the probability that the completion of K2 and R4 in 2002 is part of the least-cost power development program over all the planning scenarios. This probability is defined as the sum of the relative probabilities of the scenarios in which completion of K2 and R4 in 2002 is part of the least-cost power development program.

The analysis shows that a decision to complete both K2 and R4 in 2002 has 50% probability of being least-cost. Completing K2 in 2002 and R4 in 2003 as a joint completion project has a 64% probability of being least-cost. The lower probability for R4 is accounted by the additional cost of transmission facilities needed for R4 which are not incurred for K2. A greater spread than two years in time loses the cost advantages of joint completion, and would be considered sequential completion (see below).

The probabilities that completion of K2 and R4 jointly are least-cost increase markedly towards 100% at later completion dates, as shown in the following graph.



A decision to complete K2 in 2002 and R4 one or two years later would have a higher overall probability of being least cost than the probability of completing both units in 2002. This is because the probability is relatively high that completing K2 in 2002 is least cost, and the probability that completing R4 later than 2002 is least cost increases substantially above 50%.

Evaluation was conducted of sequencing completion first of K2 and then R4 as separate projects. Under this approach, K2 was considered to be completed in 2002 and then R4 completed as a separate project in its own least-cost timing, but no sooner that 2005. A decision to sequence the completion of the units involves a total completion cost that is about 9% higher than the total cost of completing the units together. This results from the loss of the savings from incurring only one set of mobilization costs and sharing staff, parts ordering, etc., that is achieved when the units are completed together. The rationale for deliberately delaying completion of R4 is to gain additional insight on potential adverse outcomes of the key planning variables before committing the capital to complete R4. Nevertheless, the analysis shows that sequential completion of the units makes little difference to the probabilities of least-cost timing for R4 completion shown above.

K2 and R4 are the only new additions to system supply capacity that are likely to be least-cost. They are needed to substitute high cost energy produced from existing unrehabilitated fossil fuel plant, even though the present (1997) installed capacity in the power system is technically sufficient (but not economically the best) to supply system energy needs and peak load until around 2007. The other least-cost investments in supply capacity up to 2010 cover rehabilitation and upgrading of existing nuclear and fossil fuel plant. The least-cost development program is thus basically a rehabilitation program, not an expansion one. Notably, it results in a major improvement in energy efficiency and reduction in harmful emissions from power plants over present levels for the Ukrainian power system.

Decision risk

Given that a decision to complete both K2 and R4 in 2002 is not certain to be least-cost, the economic risk of proceeding with this decision should be compared with the economic risk of making other decisions about completing K2 and R4 instead. The economic risks for two other decisions were thus analyzed, namely first to complete K2 in 2002 and R4 no earlier than 2005 and later if least-cost, as indicated above; and second not to complete K2 and R4 before 2010.

For the purposes of the analysis, the economic risk of a decision about when to complete K2 and R4 is the difference between the total cost of the least-cost development program with the completion date of K2 and R4 constrained according to the decision, and the total cost of the least-cost development program without any constraint. The amount of this cost difference varies with planning scenario.

The risk of incurring excess cost from a decision about when to complete K2 and R4 arises from the uncertainty about which planning scenario will actually materialize. The least-cost timing for completing K2 and R4 under the scenario that actually happens may differ from the least-cost timing for the assumptions upon which the decision is based. The decision risk for completing the units in 2002 is that the scenario that actually occurs carries least-cost completion of one or both units in later years. The decision risk for deferring completion of R4 until 2005 or later is that the scenario that actually occurs carries least-cost completion for R4 before 2005. The decision risk for not completing the units by 2010 is that the scenario that actually occurs carries least-cost completion of one or both units before 2010.

The excess cost from this risk was assessed for each of the 27 scenarios. The analysis shows that under most scenarios (15 out of 27), there is no or negligible cost risk in deciding to complete K2 and R4 in 2002. The highest present value cost risk of this decision is $149 million, a scenario that includes the high value for K2/R4 completion cost, the low load forecast and the low fossil fuel cost. The average cost risk of completing both K2 and R4 in 2002 is $22 million.

In none of the scenarios is the exclusion of K2 and R4 least cost. The cost penalty of not completing K2 and R4 ranges from a present value of $20 million to one of $657 million. The average cost risk of not completing K2 and R4 is $322 million, which shows that there is a major cost risk in deciding not to complete them by 2010.

The present value cost of sequencing the completion of R4 after completing K2 in 2002 averages $114 million more than the cost of completing them at the least-cost timing. The present value cost of sequencing the completion of the two units averages $92 million more than the average cost of completing them together in 2002. This is because 26 of the 27 scenarios show lower cost for joint completion in 2002 over sequential completion. Hence, the decision to complete both K2 and R4 in 2002 carries the lowest cost risk of these three decisions.

Conclusion

The analysis of whether completion of K2 and R4 in 2002 is likely to be least-cost leads to the following conclusions:

- 2002 is the least-cost timing for K2 and R4 in the base case scenario;
- the completion timing of 2002 for K2 and R4 in the base case is robust in the sensitivity tests;
- completion of K2 and R4 jointly in 2002 has a 50% probability of being least cost under scenario analysis;
- completion of K2 in 2002 and R4 in 2005 or later as a sequential project is likely to be higher cost than completion of both units jointly in 2002;
- the decision to complete K2 and R4 jointly in 2002 is the least risky choice in terms of economic cost.

On the basis of these combined conclusions from the sensitivity analysis, the probability analysis and the decision risk analysis, the decision to complete both Khmelnitsky 2 and Rovno 4 in 2002 is likely to be the least-cost and least risky economic choice.

MAIN REPORT

1. Introduction

A. Purpose of the Analysis

This analysis was undertaken on behalf of the European Bank for Reconstruction and Development (EBRD) as part of the economic due diligence for completing and operating two nuclear power generating units, designated Khmelnitsky 2 ("K2") and Rovno 4 ("R4"). These units are partially completed, with approximately 80% of construction in place. Both units are located at sites already having at least one operating nuclear unit. These two partially complete units are of the Russian VVER-1000 design. Besides the Chernobyl Nuclear Power Station, the nuclear power utility, Energoatom, now operates a total of 13 nuclear generating units, eleven of which are of the VVER-1000 type and two are of the VVER-440 type.

B. Previous Studies

This study is the latest in a series of studies addressing the issue, either directly or tangentially, of whether completion of K2 and R4 are part of the least-cost power development program for Ukraine.
The studies known to be available are:

- "Ukraine – Power Sector Least Cost Investment Plan," Main Report, Lahmeyer International, July 1995
- "Economic Assessment of the Khmelnitsky 2 and Rovno 4 Nuclear Reactors in Ukraine, Science Policy Research Unit, University of Sussex, 4 February 1997 (Surrey Panel Report)
- Previous Stone & Webster Report of May, 1997

Also, the following reports have contributed information to the pool of data that could be drawn upon for this analysis:

- "Staff Appraisal Report, Ukraine, Electricity Market Development Project," World Bank, Sept. 16, 1996, Report No. 15450-UA
- "Energy Policies of Ukraine, 1996 Survey" International Energy Agency
- "Ukraine Thermal Power Plant Rehabilitation Study," Draft Main Report, Kema Consultants, August 10, 1994 and addenda, for World Bank
- "Cost Estimates and Financial Evaluations, Ukraine Thermal Power Plant Rehabilitation Study," draft report, Comprimo Consultants as sub-contractor to KEMA, 2 August, 1994, for World Bank
- "Ukraine Fossil Fuel Power Plant Efficiency Study, Main Report, ESB International, January 1994, for EBRD
- "Joint Parallel Nuclear Alternatives Study for Russia," Final Report, U.S. Dept. of Energy and Ministry of Atomic Energy of the Russian Federation,

June 1995

- "Demand-Side Management in Ukraine, Part 1: National Assessment," Final Draft Report, Hagler Bailly Consulting, Inc., September 15, 1995

In brief, the Lahmeyer study and the previous Stone & Webster Study concluded that the Khmelnitsky 2 and Rovno 4 nuclear power plants should be completed immediately as part of the least-cost development plan for the Ukrainian electricity sector. The Surrey Panel Report recommended that they not be completed. A comparison of the Surrey Panel Report's recommendations and those of this report, together with an explanation of the differences, is included in Appendix D of this report.

2. Methodology

A. Range of Alternatives

The approach to the evaluation of completing K2 and R4 considered both supply-side and demand-side options to find the long-term development program for the whole power system that meets forecast electricity demand at least total economic cost.

A considerable degree of uncertainty exists about the values that will exist for a number of key variables in this analysis. An important element in the analysis has thus been to identify these key variables and to establish a range of their possible outcomes. Previous studies have offered valuable insights on these choices. The key variables are:

- Energy demand and peak load forecast
- K2 and R4 completion cost (including decommissioning and transmission)
- Fossil-fuel unit rehabilitation costs
- Fuel costs

Considerable research, as noted above, has been performed on possible equipment alternatives that could be used to improve the performance of the Ukrainian electricity generating stations. Proposals have included:

- A broad range of fossil-fueled power plant rehabilitation
- Nuclear unit completion for partially-constructed units
- Performance upgrade of existing nuclear units
- New stand-alone fossil-fueled power plants
- Combined heat and power production facilities
- Completion of a partially-constructed pumped storage power plant
- Solar, wind and biomass-fueled power plants

Also, energy conservation measures have been proposed and studied for their applicability, as noted above in the list of studies previously undertaken. The use of energy conservation measures is considered especially important since the large base of industrial use has been shown to be much less energy-efficient than similar industries in the West. This has been largely attributed to the lack of requirement for users to pay for the amount of electricity used at cost of service rates.

The only assumption that was treated as certain for the analysis was the permanent closure of Chernobyl Nuclear Power Station in 2000 in accordance with the Memorandum of Understanding between Government of Ukraine and the G-7 of 20 December 1995.

In addition, the existing production capacity of the Ukrainian power system was considered, for which an amount of 50,000 MW was included in the analysis. This total comprised 24% nuclear power (excluding Chernobyl NPP), 56% fossil fuel plant, 9% hydropower capacity, and 11% combined heat and power plant. Some of the fossil fuel plant was assumed to be retired during the planning period up to 2010 according to a schedule provided by the Ministry of Energy and Electrification in Kiev.

The existing fossil fuel generating plants need extensive repair and rehabilitation. Large quantities of natural gas are being used as a co-firing fuel in most units to maintain combustion and to provide adequate boiler heat input for full load operation. Various levels of co-firing, ranging up to 50%, are being used. Reports of low availability of almost all the fossil-fueled units, deteriorating condition of most of the boiler and flue gas pass equipment at these plants, and poor quality coal causing pulverizer, electrostatic precipitator, and other problems indicated that a major redevelopment effort will eventually be required. Alternatives that reflected the need for repair or replacement were thus considered. Also, the opportunity to take advantage of already-completed construction, which will have to be paid for anyway, was considered. This included the two nuclear units and the Dniester Pumped Storage Station.

Energy conservation and demand-side management programs that would be competitive with supply-side costs were explored and included. The Hagler Bailly Study has sufficient documentation of the DSM programs for modeling purposes, so all of the programs included in that study were considered, a total potential of approximately 500 MW.

Three different new plant types were included in the list of alternatives. These were: coal-fired atmospheric fluidized bed combustion (AFBC) boiler steam plant, gas-fired combined cycle, and gas-fired open cycle combustion turbines. These options represent a range of fuel costs, capital costs and efficiencies considered reasonable for Ukrainian conditions. The new AFBC plant was assumed to burn the residue from washed coal, known as schlamm, mixed with a small percentage of unwashed Ukrainian coal (based on the ongoing modernization of Unit 4 at Starobeshevo Power Station). The rehabilitation option with an AFBC replacement boiler combines with the existing turbine and generator to extend the working life of the production unit. Besides taking advantage of the low economic cost of schlamm and the sunk costs in turbines and generators, the AFBC option also virtually eliminates sulfur emissions and the use of gas and heavy fuel oil to support combustion of low quality coal, and it greatly reduces ash emissions.

Renewables such as solar and wind energy plants were not considered as options for new capacity in this study since no background work was found to support solarization, wind potential or costs for these types of generation in Ukraine. In general, it is unlikely that their present high unit capital costs could be recovered at viable rates under the expected low level of system marginal prices in the Ukrainian wholesale electricity market. Also, a brief look at climatological conditions produced a discouraging outlook for them (except for a modest amount of windpower in Crimea).

Use of existing combined heat and power (CHP) plants was included. These included the plants in the Kiev and Kharkov areas as well as 3000 MW of CHP plants in other areas.

No direct consideration of new CHP plants was given in the general mix of alternatives. However, some separate cases were analyzed that modeled CHP plants burning gas in order to test their viability as differentiated from other plant types. It was found that the CHP plant costs, even with favorable cost splits with the heating loads, were no more competitive than other plant types already represented. Also, the electric system peak demand period coincides with the district heating high demand, thus reducing available electricity output when it is most needed. Since this was not a study focused on the CHP issue, it was considered adequate to have new such plants represented by a surrogate that was at least as cost effective.

In the course of the data gathering for this study, there was discussion of the relative impacts of the various alternatives on the Ukrainian environment. This was not part of the terms of reference for this study (other consultants are carrying out an Environmental Impact Assessment for K2 and R4). However, since the planning model used is capable of representing the various air pollutant emissions, data for sulfur dioxide, nitrous oxides and ash emissions were entered, and the model emission rates tested against emissions published for historical periods. No attempt to monetize the emissions was made, nor was the unit dispatch modified based on emissions rates. The model was asked just to report emission amounts in tons for the scenarios analyzed.

B. Evaluation Approach

The total economic cost of a power development program comprises construction costs of future investments in power supply facilities and the operating costs of both existing and new facilities. For this analysis costs are expressed in constant price terms (1997 US$) without price inflation. They exclude Ukrainian direct taxes and interest during construction. Each cost is discounted to a present value (in 1997) at a rate that reflects the opportunity cost of capital to Ukraine. A 10% rate (in real terms net of inflation) was used for this analysis. The total economic cost for a development program is the sum of the discounted costs. Thus, there is a specific economic cost for each power development program. The program with the lowest economic cost is considered to be the least-cost program. Completion of K2 and R4 by a certain date, notably 2002, is considered to be economically justified if it is included in the least-cost program.

Different power development programs are evaluated under a particular set of values for the numerous planning variables involved in the analysis. In view of the considerable uncertainty about estimating future economic conditions in Ukraine, however, there is a low probability that a single planning scenario would in fact occur. Hence, the robustness of the least-cost status of completing K2 and R4 by 2002 is tested over a range of values for key planning variables - demand for power, construction costs for new capacity additions including K2/R4 and fossil-fueled plant, prices of fuels (coal, gas, heavy fuel oil), and costs of rehabilitating existing fossil fuel plant. This range is represented by three values, low, middle, and high for each variable. Each combination of values for the variables comprises a planning scenario. The combination of middle values defines a base case planning scenario that is used as a reference case. The economic justification for completing K2 and R4 is confirmed if the least-cost development programs for most planning scenarios includes the completion of K2 and R4 in 2002.

A period of 14 years, covering the years 1997 to 2010, was used for planning investments in system capacity. In order to account for costs and benefits that might accrue after this period from investments undertaken during the planning period, an extension period of 30 years to 2040 was used for discounting to present values such benefits and costs.

Two results were sought from the analysis:

1. **Probabilities -** An estimate of the probability that completion of K2 and/or R4 by a certain year would be part of the least-cost plan. This probability was derived for a planning scenario that was defined by a combination of the various key drivers. Each of the four key drivers has three possible values. This produces a potential of 81 different scenarios for each K2/R4 completion approach, either joint completion, or sequential completion.

2. **Decision Cost Risk -** An assessment of exposure to excess cost over the least-cost option of decisions about completing K2 and R4 under the range of planning scenarios. This assessment is made for each scenario by comparing the present value of meeting forecast demand with a development program that includes the completion of K2 and R4 on specific dates, with the present value of the least-cost development program for the scenario. Zero cost risk indicates that the decision to complete K2 and R4 on the specified date(s) would be part of the least-cost development program for the planning scenario.

Three decisions were analyzed in this way regarding the completion of K2 and R4. They are:

1. **Joint Completion** - K2 and R4 are completed as a joint project, even if the dates of their completion are separated by a year or more. In this approach only one set of mobilization costs are incurred, and some sharing of common staff, parts ordering, etc., is achieved. The decision risk in this case occurs if scenarios for the future emerge in which completion of both units in 2002 is not least-cost.
2. **Sequential Completion** - K2 is completed in 2002, and R4 is completed no sooner than 2005 as a separate effort. R4 is completed after K2 because of the additional US$67 million (in 1997 prices) cost for constructing transmission facilities to integrate Unit 4 at Rovno Nuclear Power Station into the national power transmission system, whereas no investment for transmission interconnection is needed for K2. The decision risk in this case occurs if future scenarios emerge in which completing R4 before 2005 is least-cost or completing K2 after 2002 is least-cost.

3. **No Completion –** Neither K2 and R4 are not completed by the end of the planning period, namely 2010. The decision risk in this case occurs if future scenarios emerge in which completion of one or both units before 2010 is least-cost.

Each approach has a different completion cost for each unit. That is, joint completion of the units has three possible completion costs, High, Middle and Low. Likewise, sequential completion of the units has three other possible completion costs - High, Middle and Low. The combined cost of completing K2 and R4 sequentially exceeds that of completing them jointly by 9% of the joint completion cost, amounting to US$92 million in the Low case for completion cost, US$110 million in the Middle case, and US$141 million in the High case.

C. Model Description

The computer model used to conduct this study was the Electric Power Research Institute's EGEAS model. The model was originally developed in 1982 for the Electric Power Research Institute (EPRI) by Stone & Webster and the Massachusetts Institute of Technology. EGEAS is a long-term cost-optimizing model based on use of load duration curves. It includes both production costs and capital costs in its optimization process. It uses either dynamic programming or Benders Decomposition optimization techniques at the user's choice. In this study optimization was performed using dynamic programming. Since its original development Stone & Webster has maintained and upgraded the model to include modeling of demand-side management, emissions compliance planning, and competitive market analysis. It will model limited fuel use, typical weeks per month with three sub-weeks per week, variation of cost and performance parameters between and within years, and a full range of escalation rates and parameter multipliers. Both bid-based pools and traditional dispatch are available by switch setting in the model's controls.

3. Data Development

A. Sources

The preparation of the data for use in this analysis was a three-step process. Step one was to extract as much as possible of the needed data from published reports. This was accomplished with guidance from a number of knowledgeable parties interested in the analysis. A number of sources had been identified in the course of previous analyses, including those from the World Bank, Lahmeyer, KEMA, and IEA. Meetings with representatives of the World Bank and the U.S. State Department for data gathering had been held as part of the study resulting in Stone & Webster's May 1997 report.

From the sources established during prior studies, tables of needed data were developed. Lists of missing or doubtful information were then developed. There was an extensive list of items that were potentially useful, but not verified. Insofar as possible, corroboration of data for all items was sought from two or more sources. Where second sources were not possible, a check that data values were at least reasonable, given the Ukrainian system's circumstances, were made. The elements with the most difficulty were fossil unit heat rates, fossil unit availability, unit retirement/failure facts, and coal/gas co-firing rates. Many other items had less severe degrees of uncertainty about their validity.

The second step in the data gathering process was to conduct interviews. The interviews were held at the Ministry of Energy and Electrification and Energoatom in Kiev in November 1997.

Following the interviews, a meeting was held in November at the EBRD offices in London to present the data gathered to date. This series of meetings over two days resulted in a recommendation that a comprehensive data review meeting be held in Kiev as soon as it could be organized. In the course of the two days of meetings some other data sources were offered, and some information provided.

The third step in the data gathering process was to participate in the data review meeting held at the Project Management Group's offices in Kiev in early December. In anticipation of that meeting, tables of all relevant data to be used in the analysis were prepared. These data tables were sent by EBRD to parties with particular expertise in the Ukrainian power sector and power system planning in general.

B. Review Process

The data review process was held from Tuesday, December 2 to Friday, December 5, 1997 at the offices in Kiev of Energoatom's Project Management Group. The daily meetings were attended by an average of approximately thirty people from a broad cross-section of groups. These included three people from Stone & Webster, one of whom is an expert in fossil power rehabilitation, and another who is an expert in nuclear power plant construction and licensing. Representatives of the Ukrainian Ministry of Energy and Electrification, Energoatom and the Academy of Sciences were present, some throughout the entire proceeding. Governmental groups were represented by staff members of the European Community, the U. S. Agency for International Development, and the U. S. Embassy's Office of the Commercial Attache. Engineers and other consultants working with the Project Management Group in the development of the K2 and R4 completion cost estimates were represented throughout the week. In addition to the representatives of the Ministry and the Academy, outside consultants on fuel pricing and coal industry restructuring also attended.

The process consisted of a presentation of all data items one at a time for review by the group present. Comments and suggestions were presented and discussed. The intent was to seek consensus agreement on all data items. With only a few limited exceptions, such consensus was reached. In those cases where agreement was not reached, none of which was critical to the outcome of the analysis, as it turns out, values were set by the EBRD staff after listening to the arguments favoring particular choices.

As a result of the scrutiny given in the review process, the planning data have been firmed up where more speculative values were previously available, and full advantage is taken of the engineering options available for developing the power system.

C. Planning Assumptions

Two of the World Bank's forecasts for power demand in Ukraine that were prepared in mid-1997 were used for the analysis. The World Bank's "low" forecast was used as the "middle" forecast, and the World Bank's "middle" forecast was used as the "low" forecast for the analysis. The EBRD's "middle" forecast was used as the "low" forecast for the analysis. The main difference between the latter two forecasts is that the EBRD forecast is more pessimistic about the short-term outlook up to 2000 for a turnaround in the decline in demand that has occurred since 1990.

An important consideration for specifying the planning data is the range of potential completion costs for K2 and R4. Three possible completion cost points were prepared, designated “Low”, “Middle”, and “High”. The “Low” estimate was taken as the estimate for K2 and R4 completion prepared by Project Management Group and reviewed at the Kiev meeting. These values included estimated costs (in present value terms) of decommissioning the two plants at the end of their service lives, and in R4's case the cost of additional transmission to reliably connect the plant to the Ukrainian transmission grid. The initial cost of loading fuel into the new reactors was included in the variable operating cost during the first three years of operation, and hence were not included in the economic completion cost to avoid double counting.

The “Middle” completion cost estimate was set at an increment of 20% on top of the “Low” estimate. This is based on the experience of the World Bank that the original engineering estimates of construction costs for power generation projects have been systematically below the actual construction costs by an average of about 20%.[1] The "Middle" completion cost estimate is thus an "expected" cost.

The “High” completion cost estimate is based on the 90% statistical probability that the actual completion cost will not exceed this amount. The factor of 1.28 by which the High cost estimate exceeds the Middle cost estimate is based on a normalized distribution of the ratio of actual cost to estimated cost for the group of World Bank-supported power generation projects referred to above.

The same principle was applied to determining the range of costs to be used for fossil-fueled plant rehabilitation projects. However, in the fossil unit rehabilitation costs, the “High” estimates were considered to exceed the “Middle” estimates by 20%, and the "Middle” estimate exceeds the “Low” estimate also by 20%.

Forecasts of fossil fuel prices were based on consensus trends. The cost of imported gas is not expected to change significantly in real terms over the foreseeable future, and so was held constant in the middle forecast at the current import price. The economic cost of domestically mined raw coal was taken to be about 20% below current coal tariffs in order to remove the estimated element of resource transfer from coal users to social programs that support jobs and communities in coal-mining areas in Ukraine. The price of Uranium oxide to Ukraine is not expected to deviate from trends in world market prices, which are expected to remain constant in real terms. The economic cost of this fuel includes an allowance for the cost of dealing with spent fuel. The economic cost of reclaiming schlamm from stock and transporting it to power stations is low in comparison to the cost of mined coal, and was taken to be around $8/ton.

An important aspect of the data review was to set a range for the amount of residues from washed coal, known as schlamm, that would be available for use as boiler fuel. This low-quality fuel would only be useable in atmospheric fluidized bed combustion (AFBC) boilers because of its low calorific value, low volatile matter (in the anthracitic schlamm that is available) and very high sulfur and ash content. . After some discussion among those knowledgeable about the subject at the review meeting, it was agreed to adopt as a conservative assumption that 180 million tons of schlamm would be economically recoverable from the several hundred million tons currently on the ground in Ukraine. It was also agreed that this stock would increase at the rate of 10 million tons per year from current coal washing. At nominal consumption rates for 200 MW and 300 MW units, it was agreed that twenty existing generating units - ten of each size - could be repowered with AFBC boilers with adequate lifecycle fuel stocks of a 85%/15% schlamm/raw coal mix, based on the design of the new 200 MW AFBC boiler that is being installed at Unit 4 of Starobeshevo Power Station with EBRD financing.

The availability of existing nuclear units for service was reviewed during the data gathering phase of the analysis. It was agreed that the existing units are presently able to

[1] “Estimating Construction Costs and Schedules, Experience with Power Generation Projects in Developing Countries,” World Bank Technical Paper No.325, Energy Series, 1996, pp. 23ff

sustain an availability level of 67%. There are upgrades in operating practice and hardware that are expected to be able to improve their availability to 75%. The improvements were estimated to cost US$78 million per unit and would be applied to the VVER-1000 type units over a period of ten years. These improvements in plant availability are separate from the safety improvements that have been discussed for this reactor type. The improvements in availability were modeled to increase linearly over the ten year implementation period. As a measure of the value of these improvements, their cost effectiveness was also tested at a cost of US$100 million per unit.

Appendix A contains tables showing the data used in the analysis.

D. Probabilities of Occurrence

Rather than seek a single, deterministic "forecast" based on a "most likely" value for each of the key planning variables, a probabilistic approach was adopted to deal with the broad range of possible values for these variables. Three values were selected for each variable that covered the range of possible values, designated High, Middle, and Low. This approach provides some insight on the likelihood of K2 and R4 being part of the least-cost power system development program under the uncertainty in making forecasts.

However, it is recognized that estimates of the future values of planning variables are subject to substantial uncertainty, which complicates attempts to assess the probability of their occurrence. The following four variables are critical for planning system development, and were used for defining the planning scenarios used in this analysis

- Annual system energy and peak demand
- Completion costs for K2 and R4
- Capital costs for rehabilitation of fossil-fuel generators
- Fuel costs

For the four variables, three were given probabilities of occurrence of 25%, 50% and 25% respectively for High, Middle and Low values. The fourth, K2 and R4 completion cost estimate, was given its own set of probabilities that are consistent with the distribution of actual costs to estimated cost that was used to derive the Middle and High values for the completion cost, namely 34% for the Low estimate, 40% for the Middle estimate, and 26% for the High estimate.

4. Analytical Process

The first steps of the analysis were to enter the planning information into the EGEAS computer model and test this information for accuracy. This test involved specifically including or excluding various power generation units to check their modeled performance against what was expected. All heat rates, fuel costs, non-fuel operating costs, capital costs, discount rates, etc. were checked by this process.

A check was conducted of the viability of the DSM programs included in the Hagler Bailly study. It was found that these programs were cost effective over a range of capital and operating costs. Therefore, approximately 500 MW of DSM programs were included as a fixed component of all the development programs analyzed, rather than incur the extensive additional computer time required to consider them as choices for optimization.

The economic case for the Dniester Pumped Storage Project to provide energy production/storage was specifically examined and found to be weak under all but the most extreme planning circumstances. This is explained by the Dniester Station's pumping/generation efficiency of 72% or 1.39 to 1, which is lower than the ratio of monthly on-peak cost to off-peak cost expected under future system circumstances. Therefore, the plant wouldn't be able to pay its operating and capital carrying costs out of profits from energy storage services. Hence, even though the plant may be valuable as a system control facility for such services to the grid operator as load following, energy settlement service, and frequency control, it was not considered as an option for capacity expansion in the analysis.

Tests of the value of the nuclear unit availability improvements at US$78 million per unit showed a positive value. A slightly positive value was also found at US$100 million per unit. Because of the computational burden of including these eleven units as choices in the optimization process, they were included as fixed improvements at the US$78 million cost per unit unless a specific case called for them not to be used or to be used at some other cost.

Air pollution emissions rates were set up for each generating unit for sulfur dioxide, nitrous oxides and ash. The rates for sulfur dioxide and ash were based on the sulfur and ash content of the fuel. No sulfur removal equipment was known to exist for the present plants. Electrostatic precipitators (ESPs) for existing plants were assumed to operate at an average of 90% efficiency. Nitrous oxide emissions rates were estimated from typical values for the various types of units in the system. NO_X emissions are largely functions of combustion cycle and operating temperature. NO_X reduction equipment in the form of low-NO_X burners is known to be installed on only a small subset of the units in the Ukrainian system, so none were modeled.

Emissions reduction equipment was included to varying degrees in the rehabilitation or new plant cost proposals. For the high level rehabilitation option with AFBC boilers and new units with AFBC boilers, sulfur dioxide removal was assumed to be 98% efficient. All rehabilitated and new units were assumed to have ESPs with 99% removal efficiency. Sulfur dioxide reduction for low and middle rehabilitated units was achieved by use of low sulfur washed coal. NO_X emission levels for all units were modeled as shown in the data tables.

Test cases were run to establish the air pollutant emissions rates for the system. The only comparative data available were system level emissions rates for sulfur dioxide, nitrous oxide and ash from the IEA report.[2] If the emissions totals found in the IEA report are scaled in proportion to the annual system energy, the emissions modeled approximate those from the report for sulfur dioxide and nitrous oxides. There is a difference in the ash emissions, possibly based on the assumption of higher efficiency of removal used in the IEA report (95%) than used in the current study.

Having established base conditions for the main analysis, a total of 185 optimization runs were performed to test all the planning scenarios, the decision risk profile, and other situations of interest. A total of 81 cases were devoted to direct analysis of the K2/R4 joint completion scenarios, and 16 more were performed for the sequential completion scenarios. Another 52 cases were run to test the decision risk profile. Three additional cases in the decision risk profile were calculated from other cases. The remaining 36 cases include tests of some extreme conditions and sensitivity of the outcomes to certain variable changes. These changes include tests of higher discount rates, extreme decline in demand for electricity, very low gas prices, and a test of breakeven K2/R4 completion costs. Some of the special cases were run to find the effect of a one-year delay in K2/R4 operation after completion due to delayed regulatory approval for operation, and if nuclear plant availability were to remain at 67% rather than improve to 75%.

A summary of the costs for all cases is given in Appendix B. The summary shows the scenario, the present value of all costs for the study period and total cost with extension period, and the least-cost in-service dates for K2 and R4. Appendix E shows the summary of the Base Case (all cost and performance variables at middle values) capital additions for all types of generation facilities through 2010.

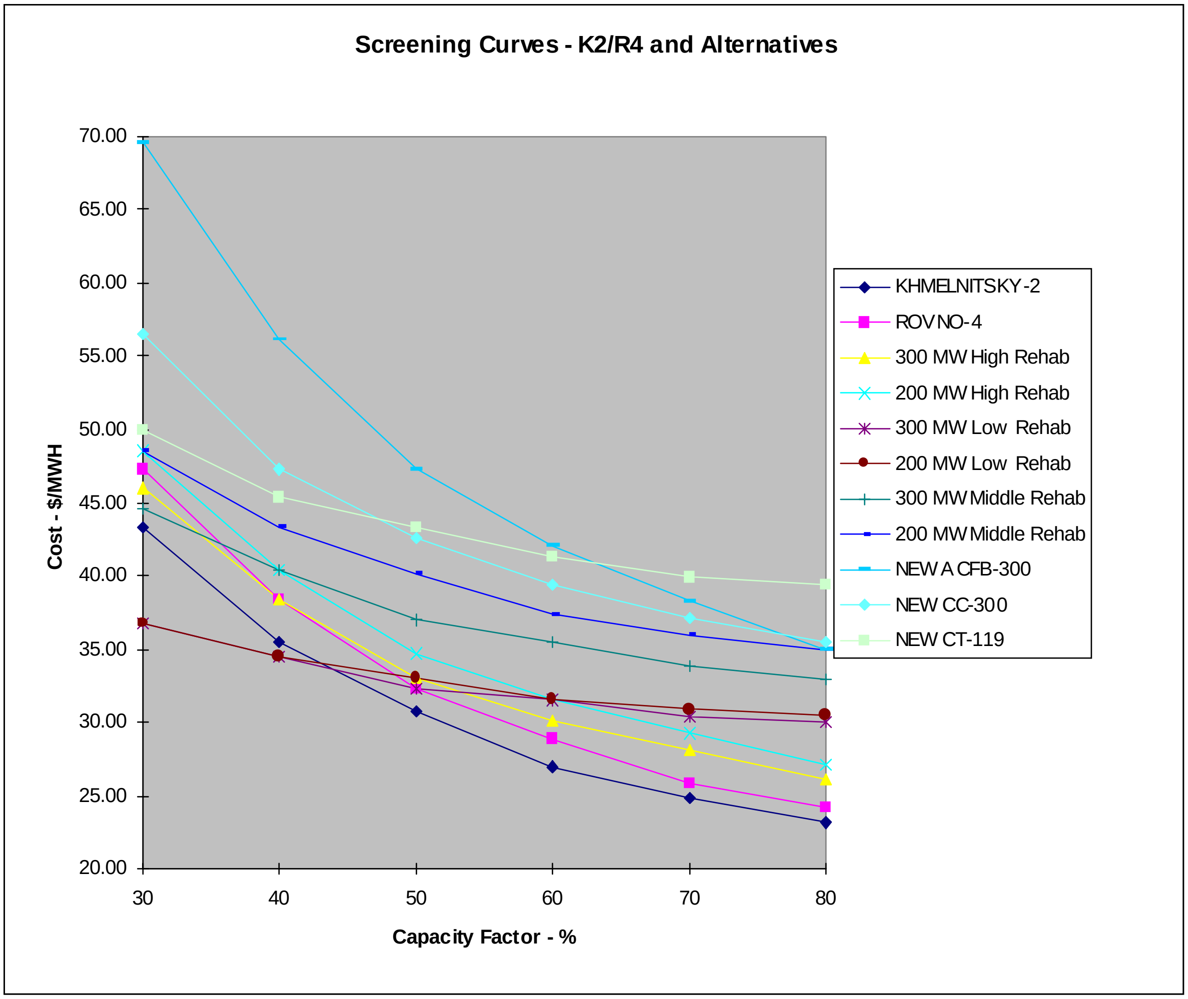
[2] IEA, p.84; also "Ukraine, Suggested Priorities for Environmental Protection and Natural Resource Management," World Bank, Report No. 12238-UA, p. VI-6.

5. Results

A. Screening Curves

Screening curves were prepared using the base case planning scenario in order to obtain a preliminary indication of the ranking of the options for adding capacity to the Ukrainian power system, including the completion of K2 and R4. A screening curve represents the change in total generation cost per Megawatt-hour of electrical energy for a generating unit that results from an increase or decrease in the utilization of the capacity of the unit (the capacity factor). Total cost includes construction costs, fuel costs and non-fuel operating and maintenance costs. The curves were prepared using the middle level values for the key variables. The screening curves do not fully represent how a particular option would fit into a power system or how its use may be influenced by load growth. The screening curves are shown in Figure 1.

Figure 1



The main indication from the screening curves is that the cost of power at capacity factors above 50% is lowest from the completed K2 and R4 units, followed closely by high level rehabilitation of fossil fuel units through the replacement of original boilers by AFBC boilers to burn an 85%/15% mixture of schlamm and unwashed coal.

B. Base case scenario

In the base case scenario (all costs and performance choices at middle value), the joint completion of K2 and R4 in 2002 is part of the least-cost development program. K2 and R4 are the only additions to system supply capacity. The remainder of investments in supply capacity cover rehabilitation and upgrading of existing nuclear and fossil fuel plant. The least-cost development program is thus basically a rehabilitation program, not an expansion one.

K2 and R4 are needed as early as 2002 to substitute high cost energy produced from existing unrehabilitated fossil fuel plant, even though the present (1997) installed capacity is technically sufficient (but not economically the best) to supply system energy needs and peak load until around 2007.

Upgrading coal-fired plant with new AFBC boilers to burn a 85%/15% mixture of schlamm and raw coal is almost as economic for substituting high cost energy as completing K2 and R4.

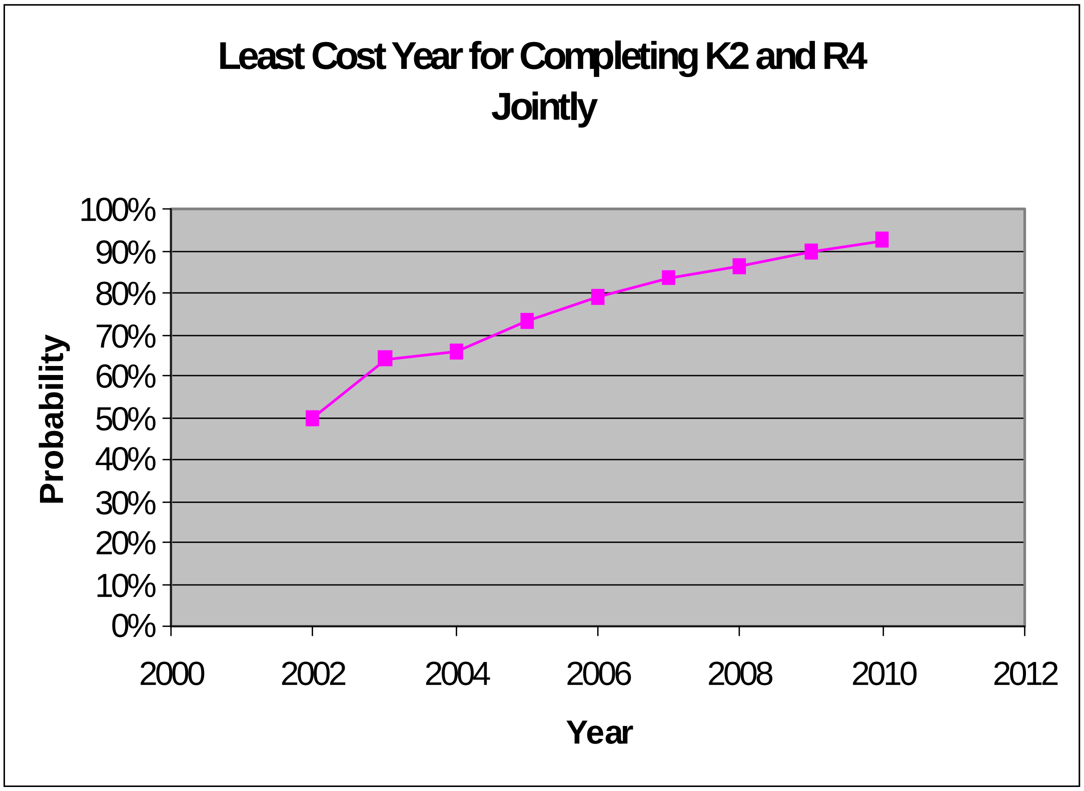
In the least-cost development program, 5,000 MW of coal-fired capacity is upgraded with AFBC boilers by 2005, and 2,000 MW of similar capacity is rehabilitated to a low level subsequently by 2010.

Because of the combination of equipment age and the lack of maintenance of existing coal-fired boilers, and high fossil fuel costs, the reliability of system supply falls below the standard used for the analysis (Loss-of-Load-Probability of no more than 24 hours per year), and the cost of operation rises significantly without the investments in K2, R4 and AFBC boilers. This is seen by comparing the costs for Cases 23, 24, and 25 with Cases 2, 1, and 16, respectively in Appendix B.

C. Probability Analysis

Joint Completion

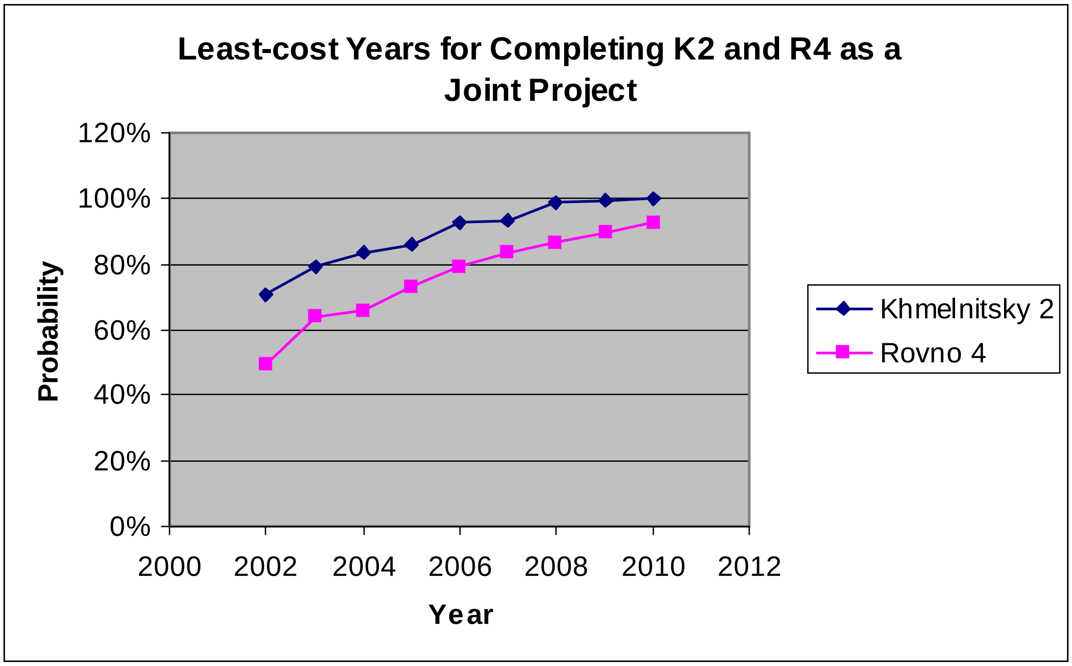
A total of 81 planning scenarios were analyzed to determine the range of least-cost installation dates for Khmelnitsky 2 and Rovno 4. Figure 2 presents graphically the probability that completion of both K2 and R4 by a particular year would be part of the least-cost power development program. The tabular information for Figure 2 is shown below it.



The potential also exists to complete K2 and R4 as a single completion project, but with a year or two between their service dates. This makes the distinction between joint completion and requiring completion of both units in the same year. The graph above for joint completion in the same year is based on the lower probability of least-cost timing between the two units, in this case R4.

The probabilities for each unit's least-cost timing as part of a joint completion project is shown in Figure 3. These probabilities are based on the recognition that there may be a gap between the units' service years. This consideration is carried through the rest of the probability analysis.

Figure 3

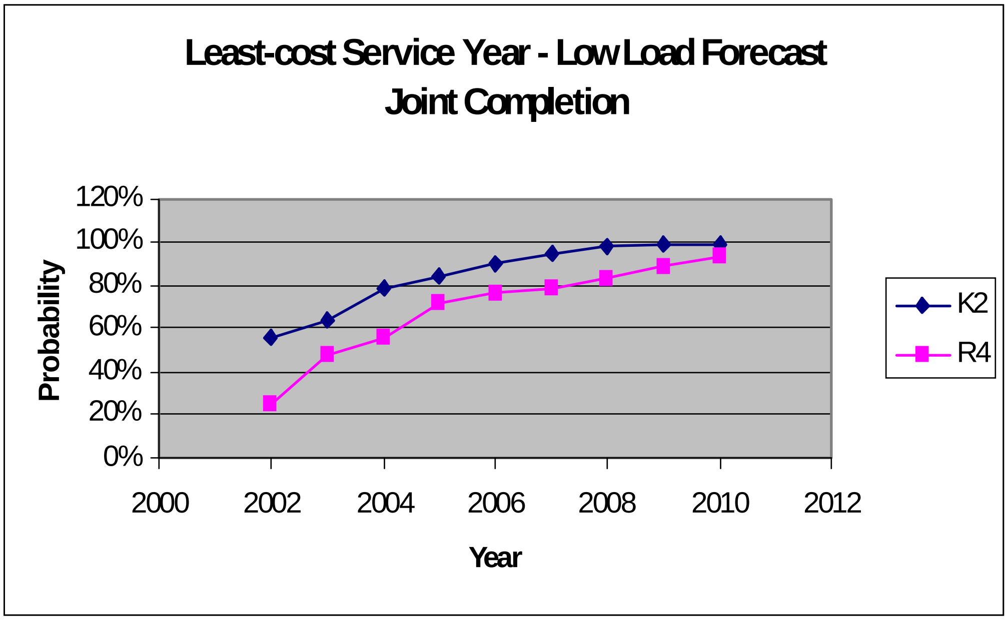


Year	Khmelnitsky 2	Rovno 4
2002	70%	50%
2003	79%	64%
2004	84%	66%
2005	86%	73%
2006	93%	79%
2007	94%	83%
2008	99%	86%
2009	99%	90%
2010	100%	93%

To illustrate the relative importance of one of these variables in combination with the others, the differentiation of outcomes has been broken down by load growth scenario for further presentation.

The decision tree for each load growth rate is shown in Appendix C. For all scenarios (27), each tree shows the probability of occurrence, the present value of the system development program, and the least-cost completion dates for K2 and R4. Each branch of the load growth tree has its own set of probabilities for least-cost completion years for K2 and R4. These are shown in Figures 4, 5 and 6, for the Low, Middle and High Load Forecasts, respectively.

Figure 4

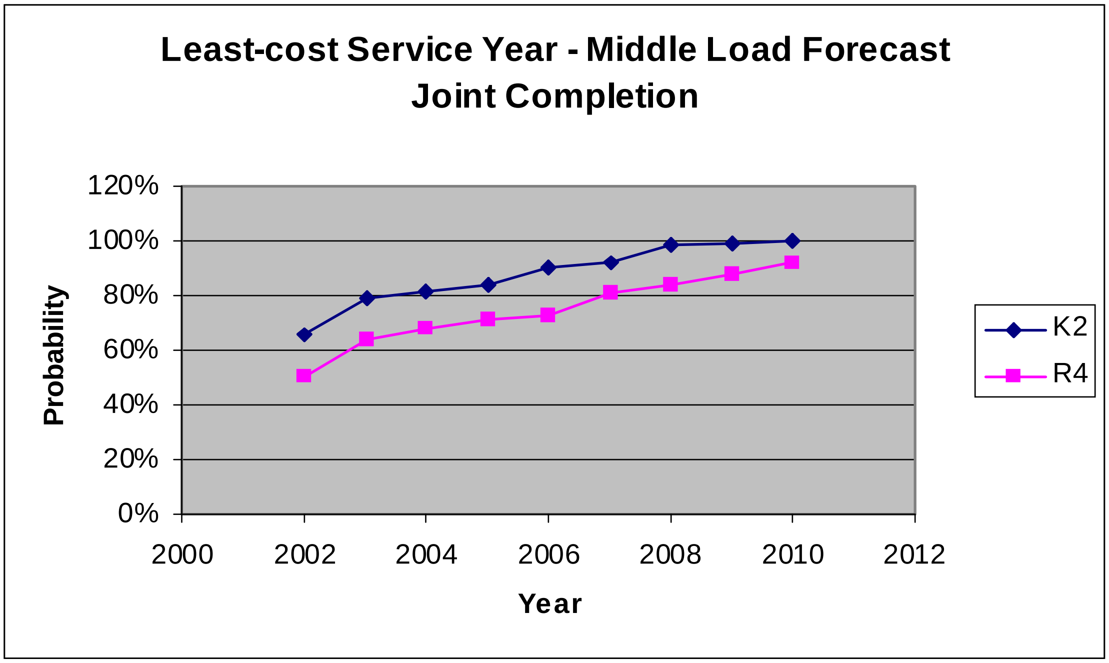


Year	Khmelnitsky 2	Rovno 4
2002	56%	26%
2003	64%	48%
2004	79%	57%
2005	85%	72%
2006	90%	76%
2007	94%	79%
2008	98%	84%
2009	99%	89%
2010	100%	94%

For the Low Load Growth scenario K2 is more than 50 % likely to be part of the least-cost system development plan. The probability of K2 being in the least-cost plan increases relatively rapidly so that by 2010 it is fully likely to part of the least-cost development. R4 is less likely to be part of the least-cost plan under low load growth, the difference between its place in the least-cost plan coming from the additional cost of transmission. The 6% probability of R4 not being part of the least-cost plan up to 2010 comes from those situations of high R4 completion cost and low fuel cost.

The probability of the Low Load Forecast occurring is estimated to be 25%.

Figure 5

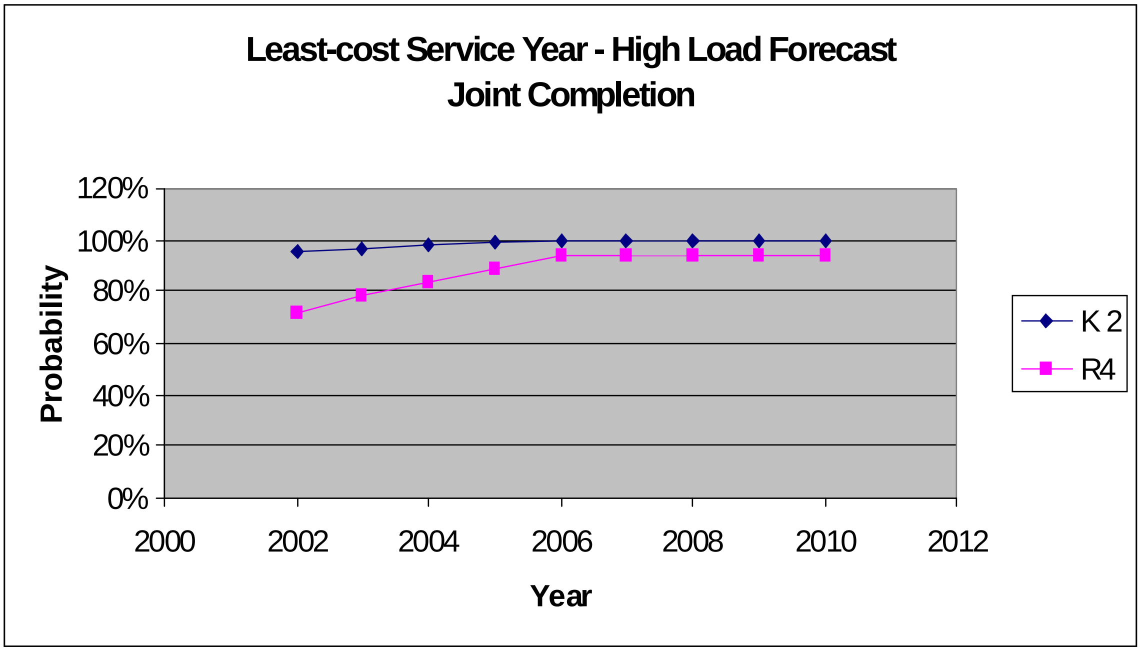


Year	Khmelnitsky 2	Rovno 4
2002	66%	51%
2003	79%	64%
2004	81%	68%
2005	84%	72%
2006	90%	73%
2007	92%	81%
2008	98%	84%
2009	99%	88%
2010	100%	92%

As in the low load growth scenario cases, K2 is fully likely to be part of the least-cost plan at some point in the study period. Because the load in this scenario is higher by 2002 than in the low case, the probability of K2 and R4 being part of the least-cost plan is higher in the early years than in the low case. However, the low load forecast, while dropping lower than the Middle forecast, does increase at a higher rate, and by 2010 is higher than the Middle forecast. Thus, R4 has a slightly lower probability of being part of the least-cost plan in 2010 than it would in the Low scenario.

The probability of the Middle load forecast occurring is estimated to be 50%.

Figure 6



Year	Khmelnitsky 2	Rovno 4
2002	95%	72%
2003	97%	79%
2004	98%	84%
2005	99%	89%
2006	100%	94%
2007	100%	94%
2008	100%	94%
2009	100%	94%
2010	100%	94%

In the High load forecast scenarios, both K2 and R4 have high levels of probability to be part of the least-cost plan from their earliest possible completion dates. The plateau reached by both K2 and R4 probabilities of completion in 2006 indicates that for the given mix of costs for other options influencing the total operational cost, the units' potentials are realized early for the scenarios in which they are advantageous.

In general, the probabilities of timing for K2 and R4 being part of the least-cost plan are influenced within each load forecast scenario by the combination of the nuclear units' completion costs and the cost of gas used for co-firing the existing coal-fired boilers.

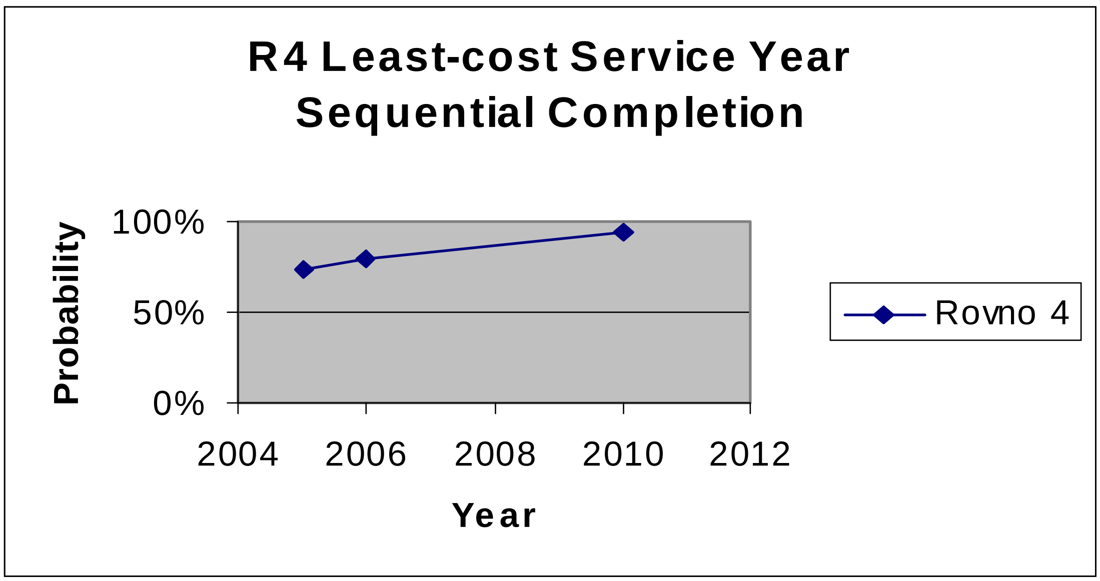
It is evident from the above graphs that there is a strong likelihood that completing K2 before 2010 would be part of the least-cost development program. Completing K2 in 2002 has better than an even chance of being part of the least-cost program. Completion of R4, while not as cost-effective as K2, has a very high probability of being part of the joint completion least-cost program. There are circumstances in which R4 would not be least-cost, mostly in scenarios entailing a combination of very high completion costs and long-term low costs of natural gas. The analysis shows that by 2002 R4 has at least a 50% chance of being part of the least-cost program.

Sequential Completion

The sequential completion analyses considered the completion cost for R4 to follow the estimating case for K2. That is, if K2 was considered to have a middle value completion cost, then R4 would also have a middle value completion cost. This reduced the potential number of cases from 243 to 81. Tests of the system costs for sequential completion were made for scenarios in which K2/R4 completion cost, load forecast and fuel costs were varied. Fossil plant rehabilitation costs were held at their middle level in all scenarios tested. This reduced the number of scenarios to be analyzed from 81 to 27. This number of cases and the data selected are sufficient to provide a good insight to the effect of sequential completion.

With K2 completed in 2002, the least-cost completion year for Rovno 4 and its probability of occurrence are shown in Figure 7, with the tabular data following.

Figure 7



Year	Rovno 4
2005	74%
2006	79%
2010	94%

There is close correlation in the least-cost timing for R4 between the joint and sequential completion approaches in the period beyond 2004, since the completion cost of K2 bears all the differential between joint and sequential completion.

D. Decision Risk

The decisions to complete K2 and R4 jointly in 2002, or K2 and R4 sequentially, or not to complete them, inherently have the potential of being wrong, whichever one is made. Thus, it is important to know what the consequences of a decision to complete or not complete K2 and R4 are, whether jointly or sequentially, in addition to the probability of outcome for a correct choice.

Joint Completion

The cost risk associated with a decision to complete K2 and R4 in a particular year is the difference between the total economic cost of the least-cost development program with K2 and R4 completed in this year, and the total economic cost of the least-cost development program without this constraint. This cost risk is evaluated for each planning scenario. Likewise, the cost risk associated with a decision not to complete K2 and R4 is the difference between the total economic cost of the least-cost development program with K2 and R4 specifically excluded and the total economic cost of the least-cost development program without this constraint. A zero value for cost risk indicates that the decision is least-cost for the scenario.

The system total cost for each of the three decisions should be computed for the full range of planning scenarios. However, because of the relatively small effect of varying the cost of rehabilitating fossil fuel plant on the least-cost timing for completing K2 and R4, it was decided to use just the middle value for this variable in order to reduce the computational burden to approximately fifty scenarios.

The distribution of cost risk for these two decisions are shown in Table 1. Of the three key independent variables used to set the scenarios, the most influential on the least-cost timing for completing K2 and R4 appears to be their completion cost.

Table 1
Present Value Decision Cost Risk for Joint Completion
of Khmelnitsky 2 and Rovno 4

K2R4 Completion Cost	Fossil Fuel Prices	Power Demand Forecast	Cost Risk of K2R4 in 2002 ($ million)	Cost Risk of no K2R4 ($ million)
High	High	High	9	248
		Middle	37	164
		Low	49	169
	Middle	High	12	244
		Middle	41	119
		Low	56	158
	Low	High	43	36
		Middle	121	21
		Low	149	20
Middle	High	High	0	501
		Middle	0	389
		Low	1	383
	Middle	High	0	496
		Middle	0	340
		Low	1	366
	Low	High	0	254
		Middle	22	184
		Low	41	174
Low	High	High	0	657
		Middle	0	546
		Low	0	537
	Middle	High	0	652
		Middle	0	496
		Low	0	521
	Low	High	0	410
		Middle	0	319
		Low	10	299
AVERAGE COST RISK			22	322

In 15 of the 27 scenarios presented in Table 1, there is no or negligible cost risk of completing K2 and R4 in 2002, since that would be the timing under the least-cost program. All of these conditions come in scenarios in which the K2/R4 completion cost is a low or middle estimate. All of the high completion cost scenarios and three of the other completion cost scenarios carry a penalty for installing both K2 and R4 in 2002. The penalty for K2/R4 completion in 2002 rather than the least-cost year is relatively small for the cases other than with high completion cost, and all the other three occur under low fuel cost scenarios. The highest present value cost risk of a decision to complete K2 and R4 in 2002 is $149 million, a scenario that includes high K2/R4 completion cost, low load forecast and low fuel cost. The average cost risk of early joint completion of K2 and R4 is $22 million.

All of the no completion cases have a cost risk, which indicates that not to complete K2 and R4 is not least-cost in any of the scenarios. This cost risk ranges from a present value of $20 million to one of $657 million. The cost risk of deciding not to complete K2 and R4 when they could have been completed for middle value completion costs, and all other planning variables have their middle values, is $340 million. The average cost risk of not completing K2 and R4 is $322 million.

In comparing the relative cost risks, it is evident that the decision to complete K2 and R4 has a large advantage, even in some of the high completion cost scenarios. Only under circumstances of high completion costs and low fuel costs is there a relative advantage of not completing K2 and R4 compared to completing them in 2002. The largest decision advantage for not completing the units is $129 million, compared to $657 million for completing them. These results support the decision to complete K2 and R4 in 2002.

Sequential Completion

Analysis for the 27 planning scenarios of the cost of completing K2 and R4 sequentially shows that the present value cost of sequencing the completion of the two units averages $114 million more than the cost with joint completion at the least-cost timing, and $92 million more than joint completion in 2002, but $208 million less than not completing K2 and R4. Hence, the decision to complete K2 and R4 in 2002 carries the lowest cost risk of the three decisions analyzed. The cost differentials of least-cost sequential completion versus least-cost joint completion, 2002 joint completion, and no completion of K2 and R4 are shown in Table 2.

Table 2
Present Value Decision Cost Risk for Sequential Completion
of Khmelnitsky 2 and Rovno 4

K2R4 Completion Cost	Fossil Fuel Cost	Power Demand Forecast	Least-cost Sequential Completion versus Least-cost Joint Completion ($ million)	2002 Joint Completion ($ million)	No Completion ($ million)
High	High	High	113	104	-135
		Middle	115	78	-49
		Low	120	71	-49
	Middle	High	113	101	-131
		Middle	98	57	-21
		Low	122	66	-36
	Low	High	114	71	78
		Middle	141	20	120
		Low	155	6	135
Middle	High	High	115	115	-386
		Middle	102	102	-287
		Low	96	95	-287
	Middle	High	115	115	-381
		Middle	100	100	-240
		Low	94	93	-272
	Low	High	101	101	-153
		Middle	92	70	-92
		Low	97	56	-77
Low	High	High	139	139	-518
		Middle	127	127	-419
		Low	118	118	-419
	Middle	High	139	139	-513
		Middle	124	124	-372
		Low	117	117	-404
	Low	High	125	125	-285
		Middle	95	95	-224
		Low	90	80	-209
AVERAGE COST RISK			114	92	-208

D. Sensitivity Tests

The justification for completing K2 and R4 in 2002 on least-cost grounds was tested for sensitivity to changes in the values of the key planning variables. Each case analyzes the effect of a change in one of the variables, keeping the middle values for all the other variables. The cases for this analysis are included in the full set reported in Appendix B.

One sensitivity test examined the effect of using higher values for the cost of capital (the discount rate) than the base value of 10% real. The values tested were 13%, 16% and

20%. The results are shown in Cases 66, 64, and 65. These cases shows that all options are pushed out in time as the cost of capital increases: to 2003 for K2 and 2005 for R4 at 13%; 2006 and 2007, respectively at 16%; and 2007 and 2009, respectively at 20%. At 20%, K2 and R4 are the only major investments in the least-cost development program.

The break-even economic cost of completing K2 and R4 jointly at which the least-cost timing for completion remains at 2002 is approximately $1490 million (Cases 61, 61A and 61B). A higher completion cost would delay the completion date under least-cost power system development. This break-even total cost is 26% higher than the "expected" middle value for joint completion cost. On the basis of the distribution for the ratio of actual cost to estimated cost that was used to derive the middle and high values for the completion cost, this break-even cost lies at a value which has a probability of between 75% and 80% of not being exceeded.

The least-cost timing of K2 and R4 could be affected by a major contraction of Ukrainian electricity demand that might be considered a possibility when large industrial consumers are obliged to pay fully in cash for their electricity consumption. This possibility was analyzed in Cases 60 and 70. In Case 60 the system load is assumed to stay at the low load forecast amount of 154,800 GWh for the remaining 10 years of the study, instead of rising to 223,500 GWh by 2010. Under these circumstances only K2 is selected as part of the least-cost program. The penalty for continued joint completion, shown in Case 60F, is $53 million. In Case 70 the system load is assumed to drop in 2000 to 145,000 GWh. From that point, the load is assumed to grow at the same rate as in the low load forecast. In this case, the least-cost program includes completion of K2 in 2002 and R4 in 2005. Joint completion of both units in 2002 has a cost penalty of only $13 million.

The extent to which the delivered cost of gas has to fall from the present level of $2.65/GJ ($2.40/GJ at the Ukrainian border) in order to displace the least-cost timing for completing K2 and R4 jointly from 2002 (for middle value K2/R4 completion costs) was also assessed. The results are shown in Cases 58 and 59, with delivered gas costs of $1.80/GJ and $2.00/GJ. Case 5 has gas costs between those for Cases 58 and 59, at $1.92/GJ. In Case 59 K2 is optimally completed in 2002 and R4 in 2004. Higher gas costs would have both units completed in 2002. Both Cases 5 and 58 show least-cost completion of K2 in 2003 and R4 in 2005.

E. Emission Benefits of K2/R4

Total air pollution emissions for all the fossil fuel plant in the power system in the base case scenario (Case 2), and K2 and R4 completed in 2002, are compared with similar conditions but without K2 and R4 (Case 2N). The substantial differences in emission levels are the savings attributable to completing K2 and R4 in 2002, and are shown in Table 6.

Table 6
System Annual Air Pollution Emissions
Metric Tons

	SO2			NOX			ASH		
	With	Without		With	Without		With	Without	
YEAR	K2/R4	K2/R4	Diff.	K2/R4	K2/R4	Diff.	K2/R4	K2/R4	Diff.
1997	1,177,899	1,177,899	0	300,461	300,461	0	1,038,820	1,038,820	0
1998	1,157,754	1,157,754	0	294,511	294,511	0	1,022,523	1,022,523	0
1999	1,127,826	1,127,826	0	285,826	285,826	0	997,469	997,469	0
2000	1,120,943	1,120,943	0	286,009	286,009	0	993,172	993,172	0
2001	1,193,871	1,193,871	0	306,668	306,668	0	1,044,564	1,044,564	0
2002	1,067,936	1,211,353	143,418	271,827	313,631	41,804	944,792	1,029,297	84,505
2003	1,113,810	1,165,883	52,073	285,105	311,056	25,951	973,233	1,013,431	40,197
2004	1,061,483	1,113,966	52,483	282,414	308,359	25,946	948,995	990,495	41,500
2005	1,011,906	1,108,233	96,327	280,136	314,955	34,819	923,802	964,995	41,193
2006	1,006,795	1,117,629	110,834	286,901	322,765	35,863	903,919	967,039	63,120
2007	1,047,717	1,071,299	23,582	301,750	321,300	19,550	902,582	951,088	48,506
2008	1,039,455	1,091,979	52,523	306,166	331,749	25,583	908,826	957,888	49,062
2009	1,033,020	1,138,433	105,413	311,239	347,073	35,834	915,908	973,850	57,942
2010	1,067,433	1,192,031	124,598	326,434	359,239	32,805	925,208	987,562	62,354

6. Conclusions

The evidence from this analysis shows that completion of Khmelnitsky 2 and Rovno 4 in 2002 are likely to be part of Ukraine's least-cost long-term power development program, with a probability of 70% for K2 and 50% for R4. These probabilities rise rapidly each year until the probability is 100% for K2 and nearly 100% for R4 as the year 2010 is approached.

The probability assessment provides only a part of the picture, however. A more complete picture emerges by comparing the cost risk of a decision to complete K2 and R4 in 2002 versus delayed completion or no completion.

In 15 of the 27 main scenarios analyzed for Joint Completion, there is no or negligible cost risk of completing K2 and R4 in 2002, since this would be their timing of the least-cost program. All of these conditions come in scenarios in which the K2/R4 completion cost is at the low or middle level. All nine of the high joint completion cost scenarios and three other scenarios carry a higher cost for installing K2 and R4 in 2002, as compared to their completion at the ideal year in the least-cost plans for those scenarios. These penalties are relatively small for the non-high completion cost scenarios, and all three of these occur under low fuel cost scenarios. The highest present value cost risk of a decision to complete K2 and R4 in 2002 is $149 million, a scenario that includes high K2/R4 completion cost, low load forecast, and low fuel costs. It should be noted, however, that there is still a $20 million penalty in this scenario for not completing K2 and R4, even if the risk of too early installation is $149 million. Thus, the net decision risk of this scenario for completing K2 and R4 in 2002 versus not completing them is $129 million.

The average present value decision cost risk of completing K2 and R4 in 2002 versus the ideal timing is $22 million.

Tests were made of all scenarios with K2 and R4 excluded. All of these scenarios have higher cost than the cost of completing the units at the least-cost timing. This indicates that some combination of completion of K2 and R4 is always better than not to complete them at all. The cost penalty of not completing K2 and R4 ranges from a present value of $20 million to a high of $657 million.

The analysis found the average cost risk of not completing K2 and R4 jointly is $322 million.

Analysis for the 27 planning scenarios for sequential completion of K2 and R4 shows that the present value economic cost of their sequential completion averages $114 million more than joint completion at the least-cost dates across the range of scenarios tested. The cost of sequential completion averages $208 million less than the cost for not completing K2 and R4.

The cost of sequential completion averages $92 million more than the cost of joint completion in 2002 across all scenarios tested.

Comparing the worst case net decision risk of $129 million found in the table of Present Value Decision Cost Risk for Joint Completion with the $92 million average cost penalty for the decision to sequence K2 and R4 completion, the cost difference is small. In all other scenarios the decision cost risk favors joint completion. Thus, it can be concluded that joint completion in 2002 is highly likely to be more cost effective than sequenced completion.

The analysis concludes that the decision to complete K2 and R4 in 2002 carries the highest economic advantage of the three decisions.

Sensitivity tests showed that the least-cost justification for the joint completion of K2 and R4 in 2002 is robust to changes in planning assumptions. Because of the generally poor condition of the bulk of the fossil-fueled generating capacity in Ukraine, many thousands of megawatts of existing coal-fired generation will require rehabilitation or replacement in the relatively near future. Once completed, K2 and R4 could provide cost-effective support for the system during an extensive and protracted program of rehabilitating fossil fuel capacity.

APPENDIX A
Data Tables

UKRAINE

K2/R4 Completion Due Diligence

Least Cost Planning Analysis

Energy Production and Peak Load Forecasts

Gross Generation Basis

	Gross Annual Energy Generation (TWh) (Including Generators' Own Use)			Load Factor (%)		Annual Peak Load (MW)			Annual Peak Load Growth Rates (%)			
	World Bank					World Bank			World Bank			
	Middle (High)	Low (Middle)	EBRD (Low)	High & Middle	Low	Middle (High)	Low (Middle)	EBRD (Low)	Middle (High)	Low (Middle)	EBRD (Low)	
Actual												Actual
1993	227.2	227.2				38,060	38,060	38,060				1993
1994	200.6	200.6				33,400	33,400	33,400				1994
1995	189.8	189.8				28,900 *	28,900	28,900 *				1995
1996	179.4	179.4				28,900 *	28,900	28,900 *				1996
Forecast												Forecast
1997	180.5	174.5	174.5	73.0%	73.0%	28,226	27,288	27,288				1997
1998	181.9	173.0	162.7	72.4%	72.4%	28,687	27,283	25,659	1.63%	-0.02%	-5.97%	1998
1999	184.8	170.8	157.1	71.8%	71.8%	29,394	27,167	24,988	2.47%	-0.43%	-2.61%	1999
2000	191.2	172.8	154.8	71.2%	71.2%	30,675	27,723	24,835	4.36%	2.05%	-0.61%	2000
2001	197.6	175.1	159.9	70.5%	70.5%	31,978	28,337	25,877	4.25%	2.22%	4.20%	2001
2002	204.2	177.6	166.2	69.9%	69.9%	33,337	28,995	27,134	4.25%	2.32%	4.85%	2002
2003	210.9	182.8	173.1	69.3%	69.3%	34,737	30,109	28,511	4.20%	3.84%	5.08%	2003
2004	217.7	188.1	180.1	68.7%	68.7%	36,178	31,259	29,930	4.15%	3.82%	4.98%	2004
2005	224.7	193.6	187.3	68.1%	68.1%	37,679	32,464	31,408	4.15%	3.85%	4.94%	2005
2006	231.4	199.2	195.2	67.5%	67.5%	39,156	33,708	33,031	3.92%	3.83%	5.17%	2006
2007	238.5	205.0	203.1	66.8%	66.8%	40,729	35,008	34,684	4.02%	3.86%	5.00%	2007
2008	245.9	210.9	211.3	66.2%	66.2%	42,383	36,351	36,420	4.06%	3.83%	5.00%	2008
2009	253.4	217.1	219.7	65.6%	65.6%	44,086	37,770	38,223	4.02%	3.91%	4.95%	2009
2010	260.9	223.5	228.2	65.0%	65.0%	45,820	39,252	40,077	3.93%	3.92%	4.85%	2010

* - Peak loads in 1995 and 1996 limited by supply circumstances

Basis - World Bank Estimate updated as of 2/18/97 for energy and
Staff Appraisal Report on Ukraine Electricity Market Development Project Dated Sept. 16, 1996, Annex 1B, p.3 for load factor information

UKRAINE
K2/R4 Completion Due Diligence
Least Cost Planning Analysis

Khmelnitsky 2 and Rovno 4 Modeling Data

	K2 + R4				K2 only	R4 only		
	Completio	Decommission	Transmission	Total	Total	Completion + Decommissio	Transm.	Total
Capital Costs = Base Cost + Physical Contingencies - ($ Millions)								
Estimated cost	869.4	47.3	67.0	983.7	550.0	458.3	67.0	525.3
Expected cost	1043.3	56.7	80.4	1180.4	660.0	550.0	80.4	630.4
Upper limit cost	1335.4	72.6	102.9	1510.9	844.8	704.0	102.9	806.9
Heat Rate (KJ/kwh)					11,000	11,000		
Fixed Operation & Maintenance Costs ($/kw/year)					30	30		
Variable Operation & Maintenance Costs ($/Mwh)					2.6	2.6		
Scheduled Maintenance (weeks/year)					9	9		
Forced Outage Rate (%)					7.7	7.7		
First Full Year of Operation					2002	2002		

Notes:
1. Cost Estimate is taken from consensus agreement reached on 4 Dec 97 by working group at Kiev data gathering meeting.
2. Initial fuel loading deducted from completion cost; fuel cost expressed in fuel cost rate for plant in which unit is located.
3. Completion costs are "overnight" construction costs.
4. Cost of transmission needs of $67 million for R4 estimated cost is shown separately.
5. Expected cost equals Estimated cost (Base cost plus physical contigencies) times 1.2. It excludes price contingencies and IDC.
6. Upper limit cost (90% confidence level) equals Expected cost times 1.28.
7. Decommissioning cost estimated at 15% of the equivalent total capital cost of $2,750/kW for constructing a "greenfield" nuclear power unit of the same design and capacity as K2 and R4, equal to $412.5/kW, and incurred after thirty years of operation. Discounting this amount to the year of initial operation at 10% discount factor of 1/17.45) yields a cost as of the in-service date of $23.64/kW, or $23.64 million for each of K2 and R4. This cost is added to the completion cost to give the equivalent overall capital cost in economic terms as of the initial in-service date.

UKRAINE
K2/R4 Completion Due Diligence
Least Cost Planning Analysis
PLANNING DATA FOR EXISTING THERMAL PLANTS

RETIREMENT DATE OR END OF SERVICE LIFE

End of service at end of year

Station Name	Unit Number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Burshtyn 1-12	1999	2000	2001	2004											
Dobrotvorsk 4-8				1999	2000	2001	2002	2003							
Krivoj Roj 1-10	2003	2005	2006	2004											
Kurakov 3-9															
Ladizhin 1-6															
Lugansk 8-15						1998	1999	2000	2000	2003	2004				
Mironov 1, 2	1998	1998													
Pridneprovsk 7-14							1998	1999	2000	2002					
Slavyansk 1, 2					1998										
Starobeshevo 4-13				1996											
Tripoli 1-6															
Uglegorsk 1-7															
Zaporozhe 1-7															
Zmiev 1-10	2000		2002		2004										
Zuev 1-4															
CHP Plants															
Kharkov 1-3															
Kiev/5 1-4															
Kiev/6 1,2															
CHP 1-10															
CHP 11-20															
CHP 21-30															

Committed plant additions:
Starobeshevo Unit 4 210MW third level rehabilitation - in service by end-2000.
Zmiev Unit 8 300MW second level rehabilitation - in service by end-2000.

UKRAINE
K2/R4 Completion Due Diligence
Least Cost Planning Analysis

PLANNING DATA FOR EXISTING NUCLEAR PLANTS

Unit	Rated Capacity (MW)	Operating Capacity (MW)	Heat Rate (KJ/KWh)	Fuel Cost ($/GJ)	Fixed O&M ($kW-Yr)	Variable O&M ($/MWh)	Scheduled Maint. (Weeks)	Forced Outage (%)
S. Ukraine - 1	1000	950	11,000	0.56	30	2.47	9	15.7%
S. Ukraine - 2	1000	950	11,000	0.56	30	2.47	9	15.7%
S. Ukraine - 3	1000	950	11,000	0.56	30	2.47	9	15.7%
Rovno - 1	402	361	11,000	0.56	30	2.47	8	3.0%
Rovno - 2	416	384	11,000	0.56	30	2.47	8	3.0%
Rovno - 3	1000	950	11,000	0.56	30	2.47	9	15.7%
Zaporozhe - 1	1000	950	11,000	0.56	30	2.47	9	15.7%
Zaporozhe - 2	1000	950	11,000	0.56	30	2.47	9	15.7%
Zaporozhe - 3	1000	950	11,000	0.56	30	2.47	9	15.7%
Zaporozhe - 4	1000	950	11,000	0.56	30	2.47	9	15.7%
Zaporozhe - 5	1000	950	11,000	0.56	30	2.47	9	15.7%
Zaporozhe - 6	1000	950	11,000	0.56	30	2.47	9	15.7%
Khmelnitzky - 1	1000	950	11,000	0.56	30	2.47	9	15.7%

Chernobyl NPP shut down by end-2000.

UKRAINE
K2/R4 Completion Due Diligence
Least Cost Planning Analysis
PLANNING DATA FOR EXISTING THERMAL PLANTS

Unit	1st Unit Install Year	Rated Capacity (MW)	Operating Capacity (MW)	Full Load Heat Rate (KJ/KWh)	Fuel Type	Fixed O&M ($kW-Yr)	Variable O&M ($/MWh)	Scheduled Maint. (Weeks)	Forced Outage (%)
Burshtyn (1-12)	1965	2280	2075	9700	Mix2	15	6.4	9	13.49%
Dobrotvor 3 (4-6)	1959	300	276	14000	Mix1	15.4	6.5	9	14.36%
Dobrotvor 2 (7-8)	1963	300	276	14000	Mix1	15.4	6.5	9	14.36%
Krivorozn	1965	2820	2820	9738	Mix1	12.4	5.9	9	20.75%
Kurakov	1972	1470	1338	9842	Mix1	16	6.1	9	13.50%
Ladizhin	1970	1800	1638	9573	Mix3	12.1	5.5	9	13.48%
Lugansk 8-15	1961	1600	1456	11141	Mix3	15.9	7	9	13.48%
Lugansk 6,7	1956	200	182	14000	Mix3	15.9	7	9	13.48%
Mironov 1		100	55	14000	Mix2	15	4	9	14.07%
Mironov 2		200	182	14000	Mix2	15	4	9	13.48%
Pridneprovsk 4-2 (7-10)	1958	600	546	10004	Mix2	15.9	6.2	9	20.75%
Pridneprovsk 4-1 (11-14)	1963	1140	1037	9940	Mix2	15.9	6.6	9	13.45%
Slavyansk 1		800	800	9941	Gas	11.7	7.5	9	20.75%
Slavyansk 2		200	185	14000	Mix2	11.7	7.5	9	14.79%
Starobeshevo 4-13	1961	1750	1593	10400	Mix2	15.8	7	9	23.19%
Tripoli 4 (1-4)	1969	1200	1200	9522	Mix2	12.3	5.5	9	20.75%
Tripoli 2 (5-6)	1971	600	561	8870	Oil	14.6	7	9	15.64%
Uglegorsk 4 (1-4)	1972	1200	1092	9163	Mix1	12.6	5.5	9	13.48%
Uglegorsk 3 (5-7)	1975	2400	2400	8787	Oil	11.7	7.5	9	20.75%
Zaporozhe 4 (1-4)	1973	1200	1092	8973	Mix2	12.6	5.5	9	13.48%
Zaporozhe 3 (5-7)	1975	2400	2400	8874	Gas	8.3	5.5	9	20.75%
Zmiev 6 (1-6)	1960	1050	955	10568	Mix2	15.4	7	9	13.44%
Zmiev 4 (7-10)	1965	1200	1100	9594	Mix2	13.4	7.5	9	14.07%
Zuev	1980	1200	1092	9241	Mix1	12.6	5.5	9	13.48%

CHP PLANTS									
Kharkov 1,2		206	206	11966	Gas	20.7	6.2	4	26.52%
Kharkov 3	1990	250	250	10281	Gas	14.7	6.7	4	29.58%
Kiev/5 1,2		200	188	11921	Mix5	19.6	6.7	4	25.09%
Kiev/5 3,4	1974	500	500	10265	Mix5	14.8	6.7	4	29.58%
Kiev/6 1,2	1982	500	500	10265	Mix5	14.8	6.7	4	29.58%
CHP 1-30		1000	970	11966	Gas	32.9	15.2	7	19.25%

Fuel Type: Mix1 - 85% Schtib, 15% Gas; Mix2 - 70% Schtib, 30% Gas; Mix 3- 50% Schtib, 50% Gas and Mazut;
Mix 4- 70% Schtib, 30% Mazut; Mix5- 30% Mazut, 70% gas

K2/R4 Ukraine Completion Due Diligence
Fuel Cost Escalation for High Fuel Cost Scenario

Fuel Type	Mix Ratios Schtib	Gas	Mazut	Cost Basis	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Mix 1	85%	15%	0%	$/GJ	1.673	1.674	1.675	1.677	1.678	1.680	1.681	1.683	1.684	1.686	1.687	1.689	1.690	1.692
				$/MBTU	1.765	1.766	1.768	1.769	1.771	1.773	1.774	1.776	1.777	1.779	1.781	1.782	1.784	1.785
				%Chg	0.088	0.088	0.088	0.088	0.089	0.089	0.089	0.089	0.090	0.090	0.090	0.090	0.091	
Mix 2	70%	30%	0%	$/GJ	1.845	1.848	1.851	1.854	1.857	1.860	1.863	1.866	1.869	1.872	1.875	1.878	1.881	1.884
				$/MBTU	1.947	1.950	1.953	1.956	1.959	1.962	1.966	1.969	1.972	1.975	1.978	1.982	1.985	1.988
				%Chg	0.159	0.159	0.160	0.160	0.160	0.161	0.161	0.161	0.162	0.162	0.162	0.163	0.163	
Mix 3	50%	25%	25%	$/GJ	2.118	2.120	2.122	2.125	2.127	2.130	2.132	2.135	2.137	2.140	2.142	2.145	2.147	2.150
				$/MBTU	2.234	2.237	2.240	2.242	2.245	2.247	2.250	2.253	2.255	2.258	2.261	2.263	2.266	2.269
				%Chg	0.115	0.116	0.116	0.116	0.117	0.117	0.117	0.118	0.118	0.118	0.118	0.119	0.119	
Mix 5	0%	70%	30%	$/GJ	2.701	2.708	2.715	2.722	2.729	2.735	2.742	2.749	2.756	2.764	2.771	2.778	2.785	2.792
				$/MBTU	2.850	2.857	2.865	2.872	2.879	2.886	2.894	2.901	2.909	2.916	2.924	2.931	2.939	2.946
				%Chg	0.253	0.254	0.254	0.254	0.255	0.255	0.255	0.256	0.256	0.256	0.256	0.257	0.257	
Gas	0%	100%	0%	$/GJ	2.650	2.660	2.670	2.679	2.689	2.699	2.709	2.719	2.729	2.739	2.749	2.760	2.770	2.780
				$/MBTU	2.796	2.807	2.817	2.827	2.838	2.848	2.859	2.869	2.880	2.891	2.901	2.912	2.923	2.933
				%Chg	0.369	0.369	0.369	0.369	0.369	0.369	0.369	0.369	0.369	0.369	0.369	0.369	0.369	

Basic Fuel Costs - $/GJ	1997	2010	Esc. Rate
Gas	2.65	2.78	0.3691%
Schtib	1.50	1.50	0.00%
Mazut	2.82	2.82	0.00%

UKRAINE
K2/R4 Completion Due Diligence
Least Cost Planning Analysis

FUEL COSTS

Fuel Type	Cost ($/GJ)	Heat Content (KJ/kg)	Ash Content (%)	Sulfur Content (%)	Water Content (%)
Schtib (Raw, Unwashed Coal)	1.50	18,227	36	2.0	10
Washed, Low sulfur Coal	1.86 rising to 1.99 in 2010	21,160	25	1.2	10
Gas - Scenario 1	2.65	33,520	0	0	0
- Scenario 2	2.65 rising to 2.78 in 2010	33,520	0	0	0
Mazut	2.82	40,600	0	2.7	2
Schlamm (Coal Washings)	0.60	13,827	50	2.0	17
Schlamm/Schtib Mix (85%/15%)	0.74	14,487	48	2.0	16
Mix 1 (85% Schtib/15% Gas)	1.67	20,521	31	1.3	N/A
Mix 2 (70% Schtib/30% Gas)	1.85	22,815	25	1.4	N/A
Mix 3 (50% Schtib/25% Gas, 25% Mazut)	2.12	27,643	18	1.7	N/A
Mix 4 (70% Schtib/30% Mazut)	1.90	24,939	25	2.2	N/A
Mix 5 (30% Mazut/70% Gas)	2.70	35,644	0	0.8	N/A

Note - Quantities of fuel available:

Washed Coal	unlimited
Schtib	unlimited
Schlamm	180 million tons in 1997 plus 10 million tons/year
Tailings	700 million tons
Mazut	unlimited
Gas	unlimited

UKRAINE
K2/R4 Completion Due Diligence
Least Cost Planning Analysis
PLANNING DATA FOR EXISTING HYDRO PLANTS

Plant Name	Operating Capacity (MW)	Annual Energy (Gwh)	Oper. & Maint. Costs Fixed $/kw/year	Oper. & Maint. Costs Variable $/MWh	Forced Outage Rate	Scheduled Maintenance (Weeks/year)	Operating Strategy
Kiev	361	635	0	1.27	0.1%	None	Peaking
Kiev Pumped Storage	235	114	0	1.44	0.1%	None	Peaking
Kanev	235	850	0	1.21	0.1%	None	Intermediate, Peaking
Kremenchuk	625	1506	0	0.76	0.1%	None	Intermediate, Peaking
Dnieprodzerzhink	352	1250	0	0.54	0.1%	None	Intermediate, Peaking
Dnieper	1515	4140	0	0.12	0.1%	None	Intermediate, Peaking
Kakhovka	300	1420	0	0.38	0.1%	None	Intermediate, Peaking
Dniester	702	800	0	0.91	0.1%	None	Peaking
Total	4325	10715					

Note - Scheduled Maintenance performed so that it does not affect plant capacity factor, therefore shown as "None"
Note - For intermediate operation, peak reservoir filling in April and May, peak energy production in October November.

UKRAINE
K2/R4 Completion Due Diligence
Least Cost Planning Analysis

PLANNING DATA FOR REHABILITATED FOSSIL PL ANTS

Unit Type	Unit Size (MW)		Capital Cost ($/kw)	1st Unit Install Year	Operating Life (Years)	Max. # Avail.		Full Load Heat Rate (KJ/KWh)	Fuel Type	Fixed O&M ($/kW/Yr	Variable O&M ($/MWh)	Scheduled Maint. (Weeks)	Forced Outage (%)	Install Outage Period
	Rated	Operatin				Each Year	Total							
First Level Rehab.	200	190	120	2000	15	4	7	9800	Washed Coal	15.00	5.50	6	8.5%	4 Mo.
	300	285	120	2000	15	4	4	9680	Washed Coal	12.00	5.00	6	8.5%	4 Mo.
Second Level Reha	200	205	400	2001	20	3	24	9570	Washed Coal	17.00	6.00	6	7.5%	1 Year
	300	310	350	2001	20	3	20	9430	Washed Coal	14.00	5.50	6	7.5%	1 Year
Third Level Rehab.	200	210	695	2001	25	2	10	9875	Schtib/Schla	17.00	6.50	6	7.0%	2 Years
	300	315	655	2001	25	2	10	9875	Schtib/Schla	14.00	6.50	6	7.0%	2 Years

First Level Rehab.- repairs, replace/repair ESP (Life of unit extended 15 years)

Second Level Rehab.- repairs, replace/repair ESP, new burners, arch firing, replace LP Turbine rotor (Life of unit extended 20 years)

Third Level Rehab. - repairs, new AFBC boiler, replace LP turbine rotor (Life of unit extended 25 years), then add $60/kw after 10 years for undefined turbine/BOP needs

Units suitable for: First Level Rehab.- 7*200 MW at Kurakhov; 4*300 MW units at Zuev.

200 MW Units suitable for Second or Third Level Rehab. - Bushtyn - 12, Lugansk - 8, Starobeshevo -9, Zmiev - 6; total = 35

300 MW Units suitable for Second or Third Level Rehab - Kiev/5 - 2 (mid only), Kiev/6 - 2 (mid only), Krivoj Roj - 9, Ladyzhinsk - 6,
Pridneprovsk - 4, Tripolie - 4, Uglegorsk - 4, Zaporozhe - 4, Zmiev - 4; total = 39

PLANNING DATA FOR NEW FOSSIL PLANTS

Unit Type	Unit Size (MW)		Capital Cost ($/kw)	1st Unit Install Year	Operating Life (Years)	Max. # Avail.		Full Load Heat Rate (KJ/KWh)	Fuel Type	Fixed O&M ($/kW/Yr	Variable O&M ($/MWh)	Scheduled Maint. (Weeks)	Forced Outage (%)
	Rated	Operatin				Each Year	Total						
Combined Cycle	300	315	750	2001	30	6	N/A	7570	Gas	7.00	3.00	4	7.0%
Combustion Turbine	119	119	375	2000	30	5	N/A	11097	Gas	3.50	1.50	2	6.0%
Atmospheric Fluidized Bed	300	315	1250	2002	35	6	N/A	9875	Schtib/Schlamm	12.50	6.00	6	7.0%
Dniester Pumped Storage(*)	7 X 324	2268	437	2000	50	3	7	N/A	72% Cycle Efficiency	6.00	1.00	4	0.1%

Note - Dniester Pumped Storage Project annual energy generation - 810 GWH per 324 MW unit

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K2/R4 Completion Due Diligence
Least Cost Planning Analysis

NOX ENVIRONMENTAL PLANNING DATA FOR FOSSIL PLANTS
(ALL UNIT TYPES)

	Heat Rate	NOX Emission Rate (*)	
Existing	(btu/kwh)	(lb/Mbtu)	(Tons/Gwh)
150 - 300 MW Coal	9500	0.800	3.45
720 - 800 MW Gas	9350	0.250	1.06
300 - 800 MW Oil	9350	0.600	2.55
Rehabilitated			
200 - 300 MW Low Level	9200	0.800	3.35
200 - 300 MW Mid Level	9000	0.400	1.64
200 - 300 MW High Level	9350	0.300	1.28
New			
300 MW Combined Cycle	7172	0.030	0.10
119 MW Combustion Turbine	10517	0.090	0.43
300 MW CFB	9350	0.300	1.28

(*) - NOX Emission Rate is in metric tons

Sources -
Existing and low level rehab - Table 2 (U.S. EPA AP-42 Emissions Factors) and Table 3 (API Emission Factors from Petroleum Industry Equipment) in "Title 1 - Ozone Attainment through NOX Control Strategies", Stephen C. Wood, AIChE 1992 Summer national Meeting, Session 64.
New and other rehab - "Development of Engineering, Cost, and Performance Data for Generation Supply Options for New England, Stone & Webster Engineering Corp. Final Report, February 1993.

UKRAINE
Khmelnitsky 2 and Rovno 4 Completion Due Diligence
Least Cost Planning Analysis

Capital Expenditure Patterns of "Overnight Cost"
and
Conflated Completion Cost Multipliers

Year	Percent Expended	Year "0" Cost Multiplier at Various Discount Rates			
		10%	13%	16%	20%
Khmelnitsky 2 and Rovno 4					
-3	39.10	49.62	53.07	56.67	61.68
-2	30.10	34.73	36.16	37.61	39.57
-1	15.30	16.05	16.26	16.48	16.76
0	6.60	6.29	6.21	6.13	6.02
+1	3.40	2.95	2.83	2.72	2.59
+2	3.40	2.68	2.50	2.35	2.16
+3	2.10	1.50	1.37	1.25	1.11
Total	100.00	113.82	118.41	123.19	129.88
High Level Fossil Rehab and New AFBC					
-3	24.00	30.46	32.58	34.78	37.86
-2	49.00	56.53	58.86	61.22	64.41
-1	19.00	19.93	20.20	20.46	20.81
0	8.00	7.63	7.53	7.43	7.30
Total	100.00	114.54	119.16	123.89	130.39
Middle Level Fossil Rehab					
-2	50.00	57.68	60.06	62.47	65.73
-1	50.00	52.44	53.15	53.85	54.77
Total	100.00	110.12	113.21	116.32	120.50
Low Level Fossil Rehab and Combustion Turbine					
-1	100.00	104.88	106.30	107.70	109.54
Combined Cycle					
-3	20.00	25.38	27.15	28.99	31.55
-2	50.00	57.68	60.06	62.47	65.73
-1	30.00	31.46	31.89	32.31	32.86
Total	100.00	114.53	119.10	123.76	130.14

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Khmelnitsky 2 and Rovno 4 Completion Due Diligence

Least Cost Planning Analysis

In-Service Date Capital Costs (US$/kW)

% Cost of Capital- 10.00%

			Overnight Construction Cost	Present Value Decommissioning or Other Delayed Costs	Overnight + Other Plant Cost	Transm. Cost	In-Service Date Capital Cost
Khmelnitsky 2							
	Low	Joint	434.70	23.64	458.3		518.4
		Sequential	526.36	23.64	550.0		622.7
	Middle	Joint	521.63	28.37	550.0		622.1
		Sequential	631.63	28.37	660.0		747.3
	High	Joint	667.69	36.31	704.0		796.2
		Sequential	808.49	36.31	844.8		956.5
Rovno 4							
	Low	Joint	434.70	23.64	458.3	67.0	585.4
		Sequential	434.70	23.64	458.4	67.0	585.4
	Middle	Joint	521.65	28.37	550.0	80.4	702.5
		Sequential	521.65	28.37	550.0	80.4	702.5
	High	Joint	667.71	36.31	704.0	102.9	899.2
		Sequential	667.71	36.31	704.0	102.9	899.2
Fossil High Rehab							
	Low	200 MW	579.00	23.13	602.1		686.3
		300 MW	546.00	23.13	569.1		648.5
	Middle	200 MW	695.00	23.13	718.1		819.2
		300 MW	655.00	23.13	678.1		773.4
	High	200 MW	834.00	23.13	857.1		978.4
		300 MW	786.00	23.13	809.1		923.4
Fossil Middle Rehab							
	Low	200 MW	333.00		333.0		366.7
		300 MW	292.00		292.0		321.6
	Middle	200 MW	400.00		400.0		440.5
		300 MW	350.00		350.0		385.4
	High	200 MW	480.00		480.0		528.6
		300 MW	420.00		420.0		462.5
Fossil Low Rehab							
	Low	200 MW	100.00		100.0		104.9
		300 MW	100.00		100.0		104.9
	Middle	200 MW	120.00		120.0		125.9
		300 MW	120.00		120.0		125.9
	High	200 MW	144.00		144.0		151.0
		300 MW	144.00		144.0		151.0
Combustion Turbine			375.00		375.0		393.3
Combined Cycle			750.00		750.0		859.0
New Coal-fired Unit with AFBC			1250.00		1250.0		1431.8

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Khmelnitsky 2 and Rovno 4 Completion Due Diligence
Least Cost Planning Analysis

In-Service Date Capital Costs (US$/kW)

% Cost of Capital- 13.00%

			Overnight Construction Cost	Present Value Decommissioning or Other Delayed Costs	Overnight + Other Plant Cost	Transm. Cost	In-Service Date Capital Cost
Khmelnitsky 2							
	Low	Joint	434.70	10.55	445.2		525.3
		Sequential	526.36	10.55	536.9		633.8
	Middle	Joint	521.63	12.65	534.3		630.3
		Sequential	631.63	12.65	644.3		760.5
	High	Joint	667.69	16.20	683.9		806.8
		Sequential	808.49	16.20	824.7		973.5
Rovno 4							
	Low	Joint	434.70	10.55	445.2	67.0	592.3
		Sequential	434.70	10.55	445.2	67.0	592.3
	Middle	Joint	521.65	12.65	534.3	80.4	710.7
		Sequential	521.65	12.65	534.3	80.4	710.7
	High	Joint	667.71	16.20	683.9	102.9	909.7
		Sequential	667.71	16.20	683.9	102.9	909.7
Fossil High Rehab							
	Low	200 MW	579.00	17.68	596.7		707.6
		300 MW	546.00	17.68	563.7		668.3
	Middle	200 MW	695.00	17.68	712.7		845.8
		300 MW	655.00	17.68	672.7		798.2
	High	200 MW	834.00	17.68	851.7		1011.5
		300 MW	786.00	17.68	803.7		954.3
Fossil Middle Rehab							
	Low	200 MW	333.00		333.0		377.0
		300 MW	292.00		292.0		330.6
	Middle	200 MW	400.00		400.0		452.8
		300 MW	350.00		350.0		396.2
	High	200 MW	480.00		480.0		543.4
		300 MW	420.00		420.0		475.5
Fossil Low Rehab							
	Low	200 MW	100.00		100.0		106.3
		300 MW	100.00		100.0		106.3
	Middle	200 MW	120.00		120.0		127.6
		300 MW	120.00		120.0		127.6
	High	200 MW	144.00		144.0		153.1
		300 MW	144.00		144.0		153.1
Combustion Turbine			375.00		375.0		398.6
Combined Cycle			750.00		750.0		893.2
New Coal-fired Unit with AFBC			1250.00		1250.0		1489.5

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Khmelnitsky 2 and Rovno 4 Completion Due Diligence
Least Cost Planning Analysis
In-Service Date Capital Costs (US$/kW)

% Cost of Capital- 16.00%

			Overnight Construction Cost	Present Value Decommissioning or Other Delayed Costs	Overnight + Other Plant Cost	Transm. Cost	In-Service Date Capital Cost
Khmelnitsky 2							
	Low	Joint	434.70	4.80	439.5		540.3
		Sequential	526.36	4.80	531.2		653.3
	Middle	Joint	521.63	5.77	527.4		648.4
		Sequential	631.63	5.77	637.4		783.9
	High	Joint	667.69	7.38	675.1		829.9
		Sequential	808.49	7.38	815.9		1003.4
Rovno 4							
	Low	Joint	434.70	4.80	439.5	67.0	607.3
		Sequential	434.70	4.80	439.5	67.0	607.3
	Middle	Joint	521.65	5.77	527.4	80.4	728.8
		Sequential	521.65	5.77	527.4	80.4	728.8
	High	Joint	667.71	7.38	675.1	102.9	932.9
		Sequential	667.71	7.38	675.1	102.9	932.9
Fossil High Rehab							
	Low	200 MW	579.00	13.60	592.6		730.9
		300 MW	546.00	13.60	559.6		690.1
	Middle	200 MW	695.00	13.60	708.6		874.7
		300 MW	655.00	13.60	668.6		825.1
	High	200 MW	834.00	13.60	847.6		1046.9
		300 MW	786.00	13.60	799.6		987.4
Fossil Middle Rehab							
	Low	200 MW	333.00		333.0		387.3
		300 MW	292.00		292.0		339.7
	Middle	200 MW	400.00		400.0		465.3
		300 MW	350.00		350.0		407.1
	High	200 MW	480.00		480.0		558.3
		300 MW	420.00		420.0		488.5
Fossil Low Rehab							
	Low	200 MW	100.00		100.0		107.7
		300 MW	100.00		100.0		107.7
	Middle	200 MW	120.00		120.0		129.2
		300 MW	120.00		120.0		129.2
	High	200 MW	144.00		144.0		155.1
		300 MW	144.00		144.0		155.1
Combustion Turbine			375.00		375.0		403.9
Combined Cycle			750.00		750.0		928.2
New Coal-fired Unit with AFBC			1250.00		1250.0		1548.7

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Khmelnitsky 2 and Rovno 4 Completion Due Diligence
Least Cost Planning Analysis

In-Service Date Capital Costs (US$/kW)

% Cost of Capital- 20.00%

			Overnight Construction Cost	Present Value Decommissioning or Other Delayed Costs	Overnight + Other Plant Cost	Transm. Cost	In-Service Date Capital Cost
Khmelnitsky 2							
	Low	Joint	434.70	1.74	436.4		566.3
		Sequential	526.36	1.74	528.1		685.4
	Middle	Joint	521.63	2.09	523.7		679.6
		Sequential	631.63	2.09	633.7		822.5
	High	Joint	667.69	2.67	670.4		869.9
		Sequential	808.49	2.67	811.2		1052.8
Rovno 4							
	Low	Joint	434.70	1.74	436.4	67.0	633.3
		Sequential	434.70	1.74	436.4	67.0	633.3
	Middle	Joint	521.65	2.09	523.7	80.4	760.0
		Sequential	521.65	2.09	523.7	80.4	760.0
	High	Joint	667.71	2.67	670.4	102.9	972.8
		Sequential	667.71	2.67	670.4	102.9	972.8
Fossil High Rehab							
	Low	200 MW	579.00	9.69	588.7		764.6
		300 MW	546.00	9.69	555.7		721.6
	Middle	200 MW	695.00	9.69	704.7		915.9
		300 MW	655.00	9.69	664.7		863.7
	High	200 MW	834.00	9.69	843.7		1097.1
		300 MW	786.00	9.69	795.7		1034.5
Fossil Middle Rehab							
	Low	200 MW	333.00		333.0		401.3
		300 MW	292.00		292.0		351.9
	Middle	200 MW	400.00		400.0		482.0
		300 MW	350.00		350.0		421.7
	High	200 MW	480.00		480.0		578.4
		300 MW	420.00		420.0		506.1
Fossil Low Rehab							
	Low	200 MW	100.00		100.0		109.5
		300 MW	100.00		100.0		109.5
	Middle	200 MW	120.00		120.0		131.5
		300 MW	120.00		120.0		131.5
	High	200 MW	144.00		144.0		157.7
		300 MW	144.00		144.0		157.7
Combustion Turbine			375.00		375.0		410.8
Combined Cycle			750.00		750.0		976.0
New Coal-fired Unit with AFBC			1250.00		1250.0		1629.8

APPENDIX B
Case Summaries

Khmelnitsky 2 and Rovno 4 Completion Due Diligence
Least Cost Planning Analysis
Case Summary

		Options Description							PVRR Results($M)		K2/R4 Status	
Case No.	Load Level	K2/R4 Completion	Fossil Rehab Cost	Fossil Fuel Cost	New AFCB Available	New CC Available	New CT Available	Nuclear Avail. Upgrade Cost	Through 2010	With Extension	K2	R4
1	WB Middle	Middle	Middle	Middle	Yes	Yes	Yes	Low	37,300	54,728	2002	2002
1N	WB Middle	Forced Out	Middle	Middle	Yes	Yes	Yes	Low	37,537	55,224	Forced Out	Forced Out
2	WB Low	Middle	Middle	Middle	Yes	Yes	Yes	Low	32,117	46,018	2002	2002
2N	WB Low	Forced Out	Middle	Middle	Yes	Yes	Yes	Low	32,250	46,358	Forced Out	Forced Out
3	WB Low	Middle	Middle	Middle	Yes	Yes	Yes	High	32,183	46,132	2002	2002
3N	WB Low	Forced Out	Middle	Middle	Yes	Yes	Yes	High	32,317	46,472	Forced Out	Forced Out
4	WB Low	Middle	Middle	Middle	Yes	Yes	Yes	Not Available	32,077	46,140	2002	2002
4N	WB Low	Forced Out	Middle	Middle	Yes	Yes	Yes	Not Available	32,223	46,533	Forced Out	Forced Out
5	WB Low	Middle	Middle	Low	Yes	Yes	Yes	Low	30,672	44,028	2003	2005
5F	WB Low	Middle	Middle	Low	Yes	Yes	Yes	Low	30,693	44,050	Forced in 2002	Forced in 2002
5N	WB Low	Forced Out	Middle	Low	Yes	Yes	Yes	Low	30,745	44,212	Forced Out	Forced Out
6	WB Low	Middle	Low	Middle	Yes	Yes	Yes	Low	31,967	45,670	2002	2003
6F	WB Low	Middle	Low	Middle	Yes	Yes	Yes	Low	31,968	45,671	Forced in 2002	Forced in 2002
6N	WB Low	Forced Out	Low	Middle	Yes	Yes	Yes	Low	32,057	45,956	Forced Out	Forced Out
7	WB Low	High	Middle	Middle	Yes	Yes	Yes	Low	32,231	46,239	2006	2010
7F	WB Low	High	Middle	Middle	Yes	Yes	Yes	Low	32,271	46,280	Forced in 2002	Forced in 2002
7N	WB Low	Forced Out	Middle	Middle	Yes	Yes	Yes	Low	32,250	46,358	Forced Out	Forced Out
8	WB Low	Middle	High	Middle	Yes	Yes	Yes	Low	32,210	46,335	2002	2002
8N	WB Low	Forced Out	High	Middle	Yes	Yes	Yes	Low	32,398	46,749	Forced Out	Forced Out
9	WB Low	Middle	Low	Low	Yes	Yes	Yes	Low	30,600	43,784	2003	2007

9F	WB Low	Middle	Low	Low	Yes	Yes	Yes	Low	30,624	43,808	Forced in 2002	Forced in 2002
9N	WB Low	Forced Out	Low	Low	Yes	Yes	Yes	Low	30,635	43,906	Forced Out	Forced Out
10	WB Low	High	Low	Low	Yes	Yes	Yes	Low	30,634	43,890	2010	Not Installed
10F	WB Low	High	Low	Low	Yes	Yes	Yes	Low	30,779	44,071	Forced in 2002	Forced in 2002
10N	WB Low	Forced Out	Low	Low	Yes	Yes	Yes	Low	30,635	43,906	Forced Out	Forced Out
11	WB Low	High	High	Middle	Yes	Yes	Yes	Low	32,346	46,579	2003	2007
11F	WB Low	High	High	Middle	Yes	Yes	Yes	Low	32,364	46,597	Forced in 2002	Forced in 2002
11N	WB Low	Forced Out	High	Middle	Yes	Yes	Yes	Low	32,398	46,749	Forced Out	Forced Out
12	WB Middle	High	Middle	Low	Yes	Yes	Yes	Low	35,653	52,230	2004	Not Installed
12F	WB Middle	High	Middle	Low	Yes	Yes	Yes	Low	35,686	52,273	Forced in 2002	Forced in 2002
12N	WB Middle	Forced Out	Middle	Low	Yes	Yes	Yes	Low	35,670	52,266	Forced Out	Forced Out
13	WB Middle	High	Low	Low	Yes	Yes	Yes	Low	35,438	51,817	2006	Not Installed
14F	WB Middle	High	Low	Low	Yes	Yes	Yes	Low	35,497	51,887	Forced in 2002	Forced in 2002
14N	WB Middle	Forced Out	Low	Low	Yes	Yes	Yes	Low	35,450	51,848	Forced Out	Forced Out
15	EBRD	High	Low	Low	Yes	Yes	Yes	Low	29,129	42,787	2010	Not Installed
15F	EBRD	High	Low	Low	Yes	Yes	Yes	Low	29,293	42,956	Forced in 2002	Forced in 2002
15N	EBRD	Forced Out	Low	Low	Yes	Yes	Yes	Low	29,136	42,859	Forced Out	Forced Out
16	EBRD	Middle	Middle	Middle	Yes	Yes	Yes	Low	30,434	44,746	2002	2003
16F	EBRD	Middle	Middle	Middle	Yes	Yes	Yes	Low	30,434	44,747	Forced in 2002	Forced in 2002
16N	EBRD	Forced Out	Middle	Middle	Yes	Yes	Yes	Low	Same as Case 18N		Forced Out	Forced Out
17 (Not Used)												
18	EBRD	High	Middle	Middle	Yes	Yes	Yes	Low	30,535	44,954	2006	2010
18F	EBRD	High	Middle	Middle	Yes	Yes	Yes	Low	30,590	45,010	Forced in 2002	Forced in 2002
18N	EBRD	Forced Out	Middle	Middle	Yes	Yes	Yes	Low	30,558	45,112	Forced Out	Forced Out
19 (Not Used)												
20	WB Low	Middle	Not Available	Middle	Yes	Yes	Yes	Low	32,440	47,120	2002	2002
20N	WB Low	Forced Out	Not	Middle	Yes	Yes	Yes	Low	32,784	47,795	Forced Out	Forced Out

			Available									
20H	WB Low	High	Not Available	Middle	Yes	Yes	Yes	Low	32,547	47,265	2003	2005
20L	WB Low	Low	Not Available	Middle	Yes	Yes	Yes	Low	32,318	46,865	2002	2002
21	WB Middle	Middle	Not Available	Middle	Yes	Yes	Yes	Low	38,260	56,761	2002	2002
21N	WB Middle	Forced Out	Not Available	Middle	Yes	Yes	Yes	Low	38,833	57,714	Forced Out	Forced Out
21H	WB Middle	High	Not Available	Middle	Yes	Yes	Yes	Low	38,415	57,024	2002	2002
21L	WB Middle	Low	Not Available	Middle	Yes	Yes	Yes	Low	38,168	56,605	2002	2002
22	EBRD	Middle	Not Available	Middle	Yes	Yes	Yes	Low	30,716	45,814	2002	2003
22N	EBRD	Forced Out	Not Available	Middle	Yes	Yes	Yes	Low	31,029	46,517	Forced Out	Forced Out
22H	EBRD	High	Not Available	Middle	Yes	Yes	Yes	Low	30,835	46,040	2004	2005
22L	EBRD	Low	Not Available	Middle	Yes	Yes	Yes	Low	30,626	45,660	2002	2002
23	WB Low	Forced Out	Not Available	Middle	No	No	Yes	Low	32,794	47,801	Forced Out	Forced Out
24	WB Middle	Forced Out	Not Available	Middle	No	No	Yes	Low	38,858	57,782	Forced Out	Forced Out
25	EBRD	Forced Out	Not Available	Middle	No	No	Yes	Low	31,038	46,553	Forced Out	Forced Out
26	WB Low	Low	Middle	Middle	Yes	Yes	Yes	Low	32,024	45,862	2002	2002
27	WB Low	Low	Middle	Low	Yes	Yes	Yes	Low	30,598	43,893	2002	2003
28	WB Low	Low	Low	Middle	Yes	Yes	Yes	Low	31,875	45,515	2002	2002
29	WB Low	Low	Low	Low	Yes	Yes	Yes	Low	30,529	43,650	2002	2003
30	WB Low	Low	High	Middle	Yes	Yes	Yes	Low	32,117	46,179	2002	2002
31	WB Low	Low	High	Low	Yes	Yes	Yes	Low	30,626	43,999	2002	2003
32	WB Low	Middle	High	Low	Yes	Yes	Yes	Low	30,700	44,137	2003	2005
32F	WB Low	Middle	High	Low	Yes	Yes	Yes	Low	30,721	44,158	Forced in 2002	Forced in 2002
32N	WB Low	Forced Out	High	Low	Yes	Yes	Yes	Low	30,794	44,349	Forced Out	Forced Out
33	WB Low	High	Middle	Low	Yes	Yes	Yes	Low	30,741	44,191	2008	Not Installed
33F	WB Low	High	Middle	Low	Yes	Yes	Yes	Low	30,848	44,312	Forced in 2002	Forced in 2002
34	WB Low	High	Low	Middle	Yes	Yes	Yes	Low	32,044	45,855	2008	Not Installed

34F	WB Low	High	Low	Middle	Yes	Yes	Yes	Low	32,122	45,933	Forced in 2002	Forced in 2002
35	WB Low	High	High	Low	Yes	Yes	Yes	Low	30,803	44,430	2005	2007
35F	WB Low	High	High	Low	Yes	Yes	Yes	Low	30,893	44,521	Forced in 2002	Forced in 2002
36	WB Middle	High	High	High	Yes	Yes	Yes	Low	37,837	55,900	2002	2003
37	WB Middle	Low	Low	Low	Yes	Yes	Yes	Low	35,251	51,469	2002	2002
38	WB Low	High	Low	High	Yes	Yes	Yes	Low	32,134	46,101	2007	2010
38F	WB Low	High	Low	High	Yes	Yes	Yes	Low	32,206	46,173	Forced in 2002	Forced in 2002
39	EBRD	Low	Low	Low	Yes	Yes	Yes	Low	29,037	42,528	2003	2004
39F	EBRD	Low	Low	Low	Yes	Yes	Yes	Low	29,047	42,538	Forced in 2002	Forced in 2002
40	WB Middle	High	Middle	Middle	Yes	Yes	Yes	Low	37,444	54,980	2002	2006
40F	WB Middle	High	Middle	Middle	Yes	Yes	Yes	Low	37,456	54,992	Forced in 2002	Forced in 2002
41	WB Middle	Middle	Middle	Low	Yes	Yes	Yes	Low	35,532	52,012	2002	2002
42	WB Middle	Low	Middle	Middle	Yes	Yes	Yes	Low	37,208	54,572	2002	2002
43	WB Middle	Low	Middle	Low	Yes	Yes	Yes	Low	35,440	51,856	2002	2002
44	EBRD	High	Middle	Low	Yes	Yes	Yes	Low	29,223	43,067	2008	Not Installed
44F	EBRD	High	Middle	Low	Yes	Yes	Yes	Low	29,360	43,216	Forced in 2002	Forced in 2002
44N	EBRD	Forced Out	Middle	Low	Yes	Yes	Yes	Low	29,228	43,087	Forced Out	Forced Out
45	EBRD	Middle	Middle	Low	Yes	Yes	Yes	Low	29,164	42,913	2004	2005
45F	EBRD	Middle	Middle	Low	Yes	Yes	Yes	Low	29,205	42,954	Forced in 2002	Forced in 2002
45N	EBRD	Forced Out	Middle	Low	Yes	Yes	Yes	Low	29,228	43,087	Forced Out	Forced Out
46	EBRD	Low	Middle	Middle	Yes	Yes	Yes	Low	30,343	44,591	2002	2002
47	EBRD	Low	Middle	Low	Yes	Yes	Yes	Low	29,103	42,788	2003	2004
47F	EBRD	Low	Middle	Low	Yes	Yes	Yes	Low	29,113	42,798	Forced in 2002	Forced in 2002
48	WB Low	High	High	High	Yes	Yes	Yes	Low	32,438	46,835	2002	2006
48F	WB Low	High	High	High	Yes	Yes	Yes	Low	32,457	46,854	Forced in 2002	Forced in 2002
49	WB Low	High	Middle	High	Yes	Yes	Yes	Low	32,323	46,488	2005	2010

49F	WB Low	High	Middle	High	Yes	Yes	Yes	Low	32,360	46,525	Forced in 2002	Forced in 2002
49N	WB Low	Forced Out	Middle	High	Yes	Yes	Yes	Low	32,349	46,652	Forced Out	Forced Out
50	WB Middle	High	Middle	High	Yes	Yes	Yes	Low	37,551	55,257	2002	2006
50F	WB Middle	High	Middle	High	Yes	Yes	Yes	Low	37,560	55,266	Forced in 2002	Forced in 2002
50N	WB Middle	Forced Out	Middle	High	Yes	Yes	Yes	Low	37,647	55,505	Forced Out	Forced Out
51	WB Middle	Middle	Middle	High	Yes	Yes	Yes	Low	37,406	55,004	2002	2002
52	WB Middle	Low	Middle	High	Yes	Yes	Yes	Low	37,313	54,848	2002	2002
53	WB Low	Middle	Middle	High	Yes	Yes	Yes	Low	32,205	46,263	2002	2002
54	WB Low	Low	Middle	High	Yes	Yes	Yes	Low	32,113	46,106	2002	2002
55	EBRD	High	Middle	High	Yes	Yes	Yes	Low	30,623	45,211	2006	2010
55F	EBRD	High	Middle	High	Yes	Yes	Yes	Low	30,673	45,260	Forced in 2002	Forced in 2002
55N	EBRD	Forced Out	Middle	High	Yes	Yes	Yes	Low	30,648	45,380	Forced Out	Forced Out
56	EBRD	Middle	Middle	High	Yes	Yes	Yes	Low	30,517	44,997	2002	2003
56F	EBRD	Middle	Middle	High	Yes	Yes	Yes	Low	30,518	44,998	Forced in 2002	Forced in 2002
56N	EBRD	Forced Out	Middle	High	Yes	Yes	Yes	Low	30,648	45,380	Forced Out	Forced Out
57	EBRD	Low	Middle	High	Yes	Yes	Yes	Low	30,426	44,843	2002	2002
58	WB Low	Middle	Middle	Gas - 1.80/GJ	Yes	Yes	Yes	Low	30,498	43,787	2003	2005
59	WB Low	Middle	Middle	Gas- 2.00/GJ	Yes	Yes	Yes	Low	30,961	44,489	2002	2004
60	Flat	Middle	Middle	Middle	Yes	Yes	Yes	Low	26,430	34,987	2002	Not Installed
60F	Flat	Middle	Middle	Middle	Yes	Yes	Yes	Low	26,462	35,040	Forced in 2002	Forced in 2002
60N	Flat	Forced Out	Middle	Middle	Yes	Yes	Yes	Low	26,448	35,020	Forced Out	Forced Out
61	WB Low	622.1/740	Middle	Middle	Yes	Yes	Yes	Low	32,132	46,044	2002	2002
61A	WB Low	622.1/745	Middle	Middle	Yes	Yes	Yes	Low	32,134	46,048	2002	2003
61B	WB Low	740/740	Middle	Middle	Yes	Yes	Yes	Low	32,181	46,128	2002	2002
62	WB Low	747.3/702.5	Middle	Middle	Yes	Yes	Yes	Low	32,168	46,106	2003	2002

63	WB Low	Middle	Middle	Middle	Yes	Yes	Yes	Not Available	32,174	46,329	2002	2007
	(Nuclear units kept at 67% Capacity Factor, including K2/R4)											
64	WB Low	Middle	Middle	Middle	Yes	Yes	Yes	Low	24,987	29,846	2006	2007
	(Cost of Capital = 16 %real)											
65	WB Low	Middle	Middle	Middle	Yes	Yes	Yes	Low	21,628	24,228	2007	2009
	(Cost of Capital = 20% real)											
66	WB Low	Middle	Middle	Middle	Yes	Yes	Yes	Low	28,189	36,242	2003	2005
66F	WB Low	Middle	Middle	Middle	Yes	Yes	Yes	Low	28,206	36,259	Forced in 2002	Forced in 2002
67	WB Low	Middle	Middle	Middle	Yes	Yes	Yes	Low	32,106	45,991	2002	2002
	(No restriction on number of low level rehab units)											
68F	WB Low	Middle	Middle	Middle	Yes	Yes	Yes	Low	32,225	46,156	Forced in 2002	Forced in 2002
	(One year delay in operation after completion expected in optimum time)											
69	WB Low	Middle	Middle	Middle	Yes	Yes	Yes	Low	32,162	46,138	2002	Forced Out
	(Only K2 available, no R4)											
70	Extr.Drop	Middle	Middle	Middle	Yes	Yes	Yes	Low	28,282	40,774	2002	2005
70F	Extr.Drop	Middle	Middle	Middle	Yes	Yes	Yes	Low	28,256	40,788	Forced in 2002	Forced in 2002
	(Annual Energy drops to 145,000 GWh in 2001, grows at 4% thereafter)											
71	WB Low	747.3/702.5	Middle	Middle	Yes	Yes	Yes	Low	32,181	46,118	2002	2005(earliest)
		(Deliberate separate completion, K2 separate middle completion cost, R4 separate middle completion, earliest installation date 2005)										
72	WB Low	747.3/899.2	Middle	Middle	Yes	Yes	Yes	Low	32,213	46,207	2002	2010
		(Deliberate separate completion, K2 separate middle completion cost, R4 separate high completion, earliest installation date 2005)										
73	WB Low	Middle	High	High	Yes	Yes	Yes	Low	32,303	46,592	2002	2002
75	WB Low	Low	High	High	Yes	Yes	Yes	Low	32,211	46,436	2002	2002
74	WB Low	Middle	Low	High	Yes	Yes	Yes	Low	32,252	45,911	2002	2002
76	WB Low	Low	Low	High	Yes	Yes	Yes	Low	31,960	45,755	2002	2002
77	EBRD	High	High	High	Yes	Yes	Yes	Low	30,726	45,551	2004	2006

78	EBRD	High	High	Middle	Yes	Yes	Yes	Low	30,637	45,294	2004	2006
79	EBRD	High	High	Low	Yes	Yes	Yes	Low	29,260	43,188	2006	Not Installed
80	EBRD	High	Low	High	Yes	Yes	Yes	Low	30,459	44,849	2008	2010
81	EBRD	High	Low	Middle	Yes	Yes	Yes	Low	30,373	44,595	2008	2010
82	EBRD	Middle	High	High	Yes	Yes	Yes	Low	30,607	45,325	2002	2003
83	EBRD	Middle	High	Middle	Yes	Yes	Yes	Low	30,522	45,071	2002	2003
84	EBRD	Middle	High	Low	Yes	Yes	Yes	Low	29,192	43,023	2004	2005
85	EBRD	Middle	Low	High	Yes	Yes	Yes	Low	30,385	44,668	2002	2005
86	EBRD	Middle	Low	Middle	Yes	Yes	Yes	Low	30,307	44,421	2002	2005
87	EBRD	Middle	Low	Low	Yes	Yes	Yes	Low	29,095	42,650	2004	2007
88	EBRD	Low	High	High	Yes	Yes	Yes	Low	30,516	45,170	2002	2002
89	EBRD	Low	High	Middle	Yes	Yes	Yes	Low	30,432	44,917	2002	2002
90	EBRD	Low	High	Low	Yes	Yes	Yes	Low	29,131	42,898	2003	2004
91	EBRD	Low	Low	High	Yes	Yes	Yes	Low	30,298	44,516	2002	2002
92	EBRD	Low	Low	Middle	Yes	Yes	Yes	Low	30,220	44,271	2002	2002
93	WB	High	High	Middle	Yes	Yes	Yes	Low	37,728	55,598	2002	2003
94	WB Middle	High	High	Low	Yes	Yes	Yes	Low	35,752	52,425	2002	Not Installed
94F	WB Middle	High	High	Low	Yes	Yes	Yes	Low	35,773	52,455	Forced In	
95	WB Middle	High	Low	High	Yes	Yes	Yes	Low	37,270	54,668	2002	2006
96	WB Middle	High	Low	Middle	Yes	Yes	Yes	Low	37,166	54,402	2002	2006
97	WB Middle	Middle	High	High	Yes	Yes	Yes	Low	37,682	55,639	2002	2002
98	WB Middle	Middle	High	Middle	Yes	Yes	Yes	Low	37,574	55,338	2002	2002
99	WB Middle	Middle	High	Low	Yes	Yes	Yes	Low	35,619	52,193	2002	2002
100	WB Middle	Middle	Low	High	Yes	Yes	Yes	Low	37,130	54,421	2002	2002
101	WB Middle	Middle	Low	Middle	Yes	Yes	Yes	Low	37,028	54,157	2002	2002
102	WB Middle	Middle	Low	Low	Yes	Yes	Yes	Low	35,343	51,625	2002	2003
103	WB Middle	Low	High	High	Yes	Yes	Yes	Low	37,590	55,483	2002	2002
104	WB Middle	Low	High	Middle	Yes	Yes	Yes	Low	37,482	55,181	2002	2002

105	WB Middle	Low	High	Low	Yes	Yes	Yes	Low	35,527	52,037	2002	2002
106	WB Middle	Low	Low	High	Yes	Yes	Yes	Low	37,058	54,265	2002	2002
107	WB Middle	Low	Low	Middle	Yes	Yes	Yes	Low	36,935	54,000	2002	2002

APPENDIX C
Decision Trees

Khmelnitsky 2 and Rovno 4 Completion Due Diligence
Least Cost Planning Analaysis
Joint K2/R4 Completion Program
Probability of Total System Present Value Cost and Optimal K2/R4 Installation Year

Load Forecast	K2/R4 Completion Cost	Fossil Rehab Cost	Fuel Cost	Prob-ability of Outcome	Total PV System Cost	Optimal Service Year K2	Optimal Service Year R4
			High 25%	0.813%	46,835	2002	2006
		High 25%	Middle 50%	1.625%	46,579	2003	2007
			Low 25%	0.813%	44,430	2005	2007
			High 25%	1.625%	46,488	2005	2010
	High 26%	Middle 50%	Middle 50%	3.250%	46,239	2006	2010
			Low 25%	1.625%	44,191	2008	Not Installed
			High 25%	0.813%	46,101	2007	2010
		Low 25%	Middle 50%	1.625%	45,855	2008	Not Installed
			Low 25%	0.813%	43,890	2010	Not Installed
			High 25%	1.250%	46,592	2002	2002
		High 25%	Middle 50%	2.500%	46,335	2002	2002
			Low 25%	1.250%	44,137	2003	2005
			High 25%	2.500%	46,263	2002	2002
Middle 50%	Middle 40%	Middle 50%	Middle 50%	5.000%	46,018	2002	2002
			Low 25%	2.500%	44,028	2003	2005
			High 25%	1.250%	45,911	2002	2002
		Low 25%	Middle 50%	2.500%	45,670	2002	2003
			Low 25%	1.250%	43,784	2003	2007
			High 25%	1.063%	46,436	2002	2002
		High 25%	Middle 50%	2.125%	46,179	2002	2002
			Low 25%	1.063%	43,999	2002	2003
			High 25%	2.125%	46,106	2002	2002
	Low 34%	Middle 50%	Middle 50%	4.250%	45,862	2002	2002
			Low	2.125%	43,893	2002	2003

Khmelnitsky 2 and Rovno 4 Completion Due Diligence
Least Cost Planning Analaysis
Joint K2/R4 Completion Program
Probability of Total System Present Value Cost and Optimal K2/R4 Installation Year

Load Forecast	K2/R4 Completion Cost	Fossil Rehab Cost	Fuel Cost	Prob-ability of Outcome	Total PV System Cost	Optimal Service Year K2	Optimal Service Year R4
			High 25%	0.406%	55,900	2002	2003
		High 25%	Middle 50%	0.813%	55,598	2002	2003
			Low 25%	0.406%	52,425	2002	Not Installed
			High 25%	0.813%	55,257	2002	2006
	High 26%	Middle 50%	Middle 50%	1.625%	54,980	2002	2006
			Low 25%	0.813%	52,230	2004	Not Installed
			High 25%	0.406%	54,668	2002	2006
		Low 25%	Middle 50%	0.813%	54,402	2002	2006
			Low 25%	0.406%	51,817	2006	Not Installed
			High 25%	0.625%	55,639	2002	2002
		High 25%	Middle 50%	1.250%	55,338	2002	2002
			Low 25%	0.625%	52,193	2002	2002
			High 25%	1.250%	55,004	2002	2002
High 25%	Middle 40%	Middle 50%	Middle 50%	2.500%	54,728	2002	2002
			Low 25%	1.250%	52,012	2002	2002
			High 25%	0.625%	54,421	2002	2002
		Low 25%	Middle 50%	1.250%	54,157	2002	2002
			Low 25%	0.625%	51,625	2002	2003
			High 25%	0.531%	55,483	2002	2002
		High 25%	Middle 50%	1.063%	55,181	2002	2002
			Low 25%	0.531%	52,037	2002	2002
			High 25%	1.063%	54,848	2002	2002
	Low 34%	Middle 50%	Middle 50%	2.125%	54,709	2002	2002
			Low	1.063%	51,856	2002	2002

Khmelnitsky 2 and Rovno 4 Completion Due Diligence
Least Cost Planning Analaysis
Joint K2/R4 Completion Program
Probability of Total System Present Value Cost and Optimal K2/R4 Installation Year

Load Forecast	K2/R4 Completion Cost	Fossil Rehab Cost	Fuel Cost	Probability of Outcome	Total PV System Cost	Optimal Service Year K2	Optimal Service Year R4
Low 25%	High 26%	High 25%	High 25%	0.406%	45,551	2004	2006
			Middle 50%	0.813%	45,294	2004	2006
			Low 25%	0.406%	43,188	2006	Not Installed
		Middle 50%	High 25%	0.813%	45,211	2006	2010
			Middle 50%	1.625%	44,954	2006	2010
			Low 25%	0.813%	43,067	2008	Not Installed
		Low 25%	High 25%	0.406%	44,849	2008	2010
			Middle 50%	0.813%	44,595	2008	2010
			Low 25%	0.406%	42,787	2010	Not Installed
	Middle 40%	High 25%	High 25%	0.625%	45,325	2002	2003
			Middle 50%	1.250%	45,071	2002	2003
			Low 25%	0.625%	43,023	2004	2005
		Middle 50%	High 25%	1.250%	44,997	2002	2003
			Middle 50%	2.500%	44,746	2002	2003
			Low 25%	1.250%	42,913	2004	2005
		Low 25%	High 25%	0.625%	44,668	2002	2005
			Middle 50%	1.250%	44,421	2002	2005
			Low 25%	0.625%	42,650	2004	2007
	Low 34%	High 25%	High 25%	0.531%	45,170	2002	2002
			Middle 50%	1.063%	44,917	2002	2002
			Low 25%	0.531%	42,898	2003	2004
		Middle 50%	High 25%	1.063%	44,843	2002	2002
			Middle 50%	2.125%	44,591	2002	2002
			Low 25%	1.063%	42,788	2003	2004
		Low 25%	High 25%	0.531%	44,516	2002	2002
			Middle 50%	1.063%	44,271	2002	2002

APPENDIX D

Comparison of
Surrey Panel Report and
Stone & Webster Report

Comparison
of
Surrey Panel Report
to
Most recent Stone & Webster Study

The first portion of this comparison is a response to general issues raised by the Surrey Panel concerning the reliability or usefulness of their study's information. The comments seek to show how reliability, thoroughness and robustness of the data has been improved in the past year. The latter portion of this comparison lays out the comparison of data and seeks to demonstrate why a completion or no-completion decision is supported by each study's data.

Comments to Statements made in Surrey Report

(Excerpts from Surrey Panel report are shown in *italics*.)

Executive Summary -

- *Before a decision could be taken with confidence….Much more would need to be known about five factors.*
  (i) The future trends of electricity and energy demand…..

In setting up the analysis, care was taken to use a broad range of possible outcomes in the use of electricity. This included a significant change in the use of electricity that reflects the requirement to pay for what is used. The load factor of the system was dropped from the Soviet-era level of 73% to 65%, which is a more normally expected value by Western standards for a mix of industrial commercial and residential consumption. It should be noted that this is shown on a gross generation basis, which includes generating station auxiliary power use and transmission losses, and as such will be slightly higher than a net delivered power load factor. Also, a DSM program parallel to that used in the Surrey Panel study was included in the latest study.

(ii) Whether and when the nuclear safety upgrade programme will be carried out and whether it will significantly increase the output of the existing nuclear reactors.

The continued attention to the performance of the existing nuclear units has brought new evidence to light that there are both solutions and economic value to applying those solutions. A distinction has been made now between safety upgrades, which produce no performance or availability improvement, and those factors, such as outage management, materials management, and controls improvements, which will improve output. The cost and value of improved performance is shown in the most recent Stone & Webster Study.

(iii) The effects of the thermal plant rehabilitation programme and the plan to rationalize the coal industry, raise productivity and put the industry on a commercial basis.

The effects of the early stages of the thermal rehabilitation program will not be known for several years, nor is it likely that the coal industry will rapidly turn around, given the current state of the mines and coal cleaning system. By that time most of the existing fossil-fired generation fleet will have failed or be quite unreliable. Thus, a wait-and-see approach may cause serious problems with reliability of supply. For example, if the Ukrainian economy were to recover at a rate that matched the World Bank middle load forecast, the generating system as now configured would provide below-standard reliability starting in 2003. For the lower load forecasts this would begin in 2007 or 2008. Because of the large size of the Ukrainian system, the amount of rehabilitation work required is in the order of several $Billion. To keep reliability standards by these dates action should not be postponed and then a "crash program" instituted, since this will inherently drive up costs and cause disruption of the system because so many units were unavailable as they undergo rehabilitation. This latter problem is exacerbated if K2 and R4 are not completed.

The rather pessimistic depiction of the Ukrainian coal industry given by Mr. Parker in his Supporting Paper to the Surrey Panel report appears to be seconded by ensuing conditions. The past year has not shown any improvement in coal industry performance. Continued research by international as well as Ukrainian coal experts in fact appears to show even more difficult times ahead. There was little evidence in the data gathering process conducted in Kiev in December, 1997, that restructuring of the coal industry was in process, or even likely in the near term. One major problem which was raised at that time and which cannot be "restructured" is that the coal seams in Ukraine are getting thin and deep underground. If possible, whole new mines using fresh seams will likely have to be built in order to meet the needs of the power generation industry in a restored Ukrainian economy that increases its reliance on indigenous coal.

(iv) The cost of completing K2/R4, including upgrading them where possible to current Western safety standards and of operating them (including the fuel cycle and non-fuel operations and maintenance, waste disposal and decommissioning.

Since the date of the Surrey Report considerable progress has been made in improving the cost estimates for both completion and operating costs. Decommissioning, waste disposal, fuel and non-fuel operating cost estimates have been scrutinized and included in the overall costs used to represent K2 and R4.

(v) When will the great bulk of electricity bills be paid and the cash crisis of the electricity supply industry be over?

This issue still remains and needs to be resolved. The Ukrainian government has made this a priority issue, we believe, but the results must be seen.

- *We have used a least cost planning (LCP) model as a supporting tool. However, we were cautious about relying heavily on this methodology for the following reasons:*

  (i) The model results derive from the assumptions used. If these are not fully transparent, it is impossible to know which factors are most important in determining the outcome.

The concept of transparency is important in the analysis. We have seen that the model used can produce either the Surrey Panel's results or the results shown in the most recent study, both outcomes being dependent on the data used, not the model.

> (iii) *The LCP methodology was developed for and used by vertically integrated electric utilities...The more competitive power generation becomes in Ukraine, the less relevant LCP methodology will be for the development of this sector (as in England and Wales).*

It is important to make the distinction between the model used, EGEAS, and the LCP methodology. For over a year Stone & Webster has been using the EGEAS model for extensive work in modeling competitive power markets, both in the U.S. and in several other countries. Changes introduced to the model allow bid-based pool modeling and analysis of operating income by unit. This has been used to determine profitability for plants, forward market clearing price, stranded cost effects, and asset valuation.

The question raised by the Surrey Panel about the effects of competition should be addressed more thoroughly than it has so far in any study, more from the point of view that the completion and operation of K2 and R4 will be profitable in the pool. Since they will not set the market clearing price, K2 and R4 will be paid at a rate set by other bidders. Will that be enough to cover their completion and operating costs?

Comparison of Data

There appears to be five areas in which the data used by the Surrey Panel and the most recent analysis differ. All five of these shifts tend to move the cost of construction and operation of the Ukrainian system more toward the conclusion that the completion of K2 and R4 is the economic choice. The five areas are: load forecast, fossil unit availability, fossil fuel cost, nuclear unit availability, and nuclear operations and maintenance costs.

Load Forecast

The estimated annual energy production and gross peak load at selected years for the two studies are shown in the following table.

Electricity Production Forecasts

	2000		2010	
	Peak (GW)	Energy (TWh)	Peak (GW)	Energy (TWh)
Surrey Panel				
Low	30.8	189	34.7	213
Middle	30.8	189	37.5	230
High	30.8	189	41.4	254
Current Study				
Low (EBRD)	24.8	154.8	40.1	228.2
Middle (WB Low)	27.7	172.8	39.3	223.5
High (WB Middle)	30.7	191.2	45.8	260.9

In comparing these two sets of forecasts, one can see that in general the Current Study's estimate of the energy and demand are higher in the later years, even though lower in the early years. Also, in the later years of the analysis, the Current Study assumes a lower capacity factor than the Surrey Panel. For example, the Surrey Panel's middle forecast projection for 2010 has a capacity factor of 70%, while the corresponding forecast used in the Current Study has a capacity factor of 65%. This was done to reflect changes in the electricity consumption patterns when consumers are going to have to pay for what they use.

Fossil and Nuclear Unit Availability and Operating Costs

On the last two pages of this comparison are tabulations of the operating data for fossil-fired power plants and nuclear plants used in the two studies. There are sharp differences in four areas of the data which appear to produce the shift of the economics of the completion/no-completion choice. They are fossil unit availability, fossil unit fuel costs, nuclear unit availability, and nuclear unit O & M costs.

The availability of all fossil-fuel generators is shown in weighted value for both sets of data. The value for the Surrey Panel data is 84% and for the Stone & Webster Study is 62%. Given the state of the Ukrainian generation system, the lower value appears more realistic, even if there were no fuel availability problems. The higher value would be approximately competitive with availability to be expected from a well and continuously maintained fleet of units of the Ukrainian system's service life. There has been no provision for any special overhauls that might restore the existing units to top tier performance, nor do the total non-fuel operation and maintenance costs shown, even if skewed toward the fixed side, provide enough money to repair past degradation of performance. Low level rehabilitation, which would restore the present units to service for up to 15 years at an availability of about 80% , is estimated to cost $120/kw, or about $3.38 Billion for the 28,180 MW.

Turning to the cost of fuel and its conversion rate, there is a significant drop in weighted average heat rate, about 10%, from the Surrey Panel report to those used in the Stone & Webster study. However, the cost of the fuel increased from a weighted average of $1.64/GJ to $2.28/GJ, or 39%. Most of this increase came from inclusion of the higher cost of the fuel used for co-firing, which was not included in the previous analysis. The cost of coal for existing units was consistent between studies, while gas and mazut were priced higher in the Stone & Webster study.

The higher cost of fuel, even though partially offset by lower heat rates, and the much lower availability levels contribute in combination to much higher operating costs for the fossil fuel units as modeled in the Stone & Webster study. This value difference is captured in a snapshot and simplified way for both sets of data.

The operating data for the nuclear units show essentially the reverse conditions from the fossil units. They have higher availability and lower operation and maintenance costs (at least for K2 and R4) in the Stone & Webster study than in the Surrey Panel report. The missing fixed O & M cost for the existing nuclear units in the Surrey Panel Report is not important in the analysis approach used in both studies.

The higher availability and lower fixed O & M cost for each of the two candidates for completion improve their competitiveness, moving from a cost of $19.48/MWh to $14.99/MWh, a reduction of 23%.

The following table shows the average cost of fossil generation (even though incremental or marginal cost would be proper) for 2000 MW at the composite cost rates and availability for the two studies, and compares that to the production costs for K2 and R4 plus charges for completion capital used in the two studies. It is evident from this comparison that the data produces two logically different conclusions.

Total Annual Costs of Power and Capital

2000 MW of Capability

	Surrey Panel	Stone & Webster
Fossil		
Energy Cost Rate	$25.08/MWh	$31.30/MWh
Nuclear		
Energy Cost Rate	19.48	14.99
Difference	5.60	16.31
Total Power cost differential (2000 MW at 75% capacity factor)	$73.6 million	$214.3 million
Nuclear Capital Carrying Cost	-$127.3 million	-$125.2 million
Advantage of K2 and R4 Completion	-$53.7 million	$89.1 million

While this table presents the results in a somewhat simplified form, it does show the same switch found in the more complex analyses performed by the computer model.

The Surrey Panel Report states in the Conclusions section of its Executive Summary,

- *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.*

This conclusion frames the situation as being only one of installed capacity. The situation facing the Ukrainian system, however, is not one of just raw capacity, but one of economic and reliable energy production. The small example shown in the table above is based on the idea that an investment of capital will produce lower system costs than owning and operating the new facility. In this case the principle is being applied to K2 and R4 completion, but it can be applied to any facility. As such, it is in keeping with the energy efficiency objectives, and in some respects shows the way for market-based reforms that will result in lowering electricity costs to the public.

The latest Stone & Webster study shows that meeting the future needs of the Ukrainian electricity sector will not be an either-or choice on K2 and R4 completion, but a long series of choices of what cost-effective facilities should be streamed into the process. K2 and R4 are part of a larger process, which will include major rehabilitation work on the existing fossil units, refurbishment or replacement of CHP plants, new integration of the Ukrainian system to the rest of the surrounding network, and other choices.

Generating Plant Performance Comparison
Data as Used in Surrey Panel Report

Station	Capacity		Full Load	Outage Rates		Availability	Fuel Price	O & M Costs		Energy Cost @
	Rated	Operating	Heat Rate (KJ/kwh)	Sch.Maint. (Weeks)	Forced (%)	Net (%)	($/GJ)	Fixed ($/kw-yr)	Variable ($/MWh)	Max. Availability ($/MWh)
Fossil										
Burshtyn	2280	2100	10,467	4	6	86%	1.52	36.00	2.80	23.47
Kurakhov	1470	1330	10,844	4	6	86%	1.52	42.00	4.10	26.14
Ladizhin	1800	1776	9,672	5	8	82%	1.52	34.80	4.10	23.62
Zuev	1200	1160	10,020	5	6	84%	1.52	36.00	2.80	22.90
Krivorozn	3000	2820	10,321	5	7	83%	1.52	34.80	4.10	24.55
Lugansk-8	1400	1304	11,180	4	6	86%	1.52	36.00	2.80	24.55
Lugansk-2	200	190	12,498	3	6	88%	1.52	48.00	4.00	29.21
Mironov-1	60	55	16,161	4	7	85%	1.52	48.00	4.00	34.99
Mironov-2	200	180	14,446	4	7	85%	1.52	48.00	4.00	32.38
Pridniprovsk-4-1	1140	1028	10,259	5	7	83%	1.52	34.80	4.10	24.46
Pridniprovsk-4-2	600	580	11,012	3	6	88%	1.52	46.80	4.20	26.99
Slavyansk-1-1	750	715	10,593	6	8	80%	1.52	32.40	3.80	24.50
Slavyansk-1-2	720	670	10,091	6	7	81%	2.05	26.40	2.60	26.99
Slavyansk-2	200	170	12,603	3	5	89%	2.05	58.80	2.90	36.26
Starobeshevo	1750	1600	10,614	8.5	7	77%	1.52	42.00	4.10	26.49
Tripoli-4	1160	1120	9,881	5	7	83%	1.52	34.80	4.10	23.88
Tripoli-2	600	588	9,881	5	6	84%	2.05	30.00	2.80	27.11
Zmiev-4	1100	1024	10,070	5	7	83%	1.52	34.80	4.10	24.17
Zmiev-6	1050	990	10,559	4	6	86%	1.52	42.00	4.10	25.71
Uglegorsk-4	1200	1080	10,321	5	6	84%	1.52	36.00	2.80	23.36
Uglegorsk-3	2250	2025	9,672	5.5	7	82%	2.05	26.40	2.60	26.08
Zaporozhe-4	1200	1140	10,153	5	6	84%	1.52	36.00	2.80	23.10
Zaporozhe-3	2250	2190	9,253	5.5	8	81%	2.05	26.40	2.60	25.27
Dobrotvorsk-2	300	280	10,761	3	5	89%	2.05	48.00	2.90	31.10
Dobrotvorsk-3	300	270	10,300	3	5	89%	2.05	48.00	2.90	30.16
Composite	28,180	26,385	10,285			84%	1.64			25.08
Nuclear										
Zaporozhe 1	1000	950	10,552	13	15	60%	0.79	0	2.2	10.54
Zaporozhe 2	1000	950	10,552	13	15	60%	0.79	0	2.2	10.54
Zaporozhe 3	1000	950	10,552	13	15	60%	0.79	0	2.2	10.54
Zaporozhe 4	1000	950	10,552	13	15	60%	0.79	0	2.2	10.54
Zaporozhe 5	1000	950	10,552	13	15	60%	0.79	0	2.2	10.54
Zaporozhe 6	1000	950	10,552	13	15	60%	0.79	0	2.2	10.54
So. Ukraine 1	1000	935	10,552	13	15	60%	0.59	0	2.5	8.73
So. Ukraine 2	1000	935	10,552	13	15	60%	0.59	0	2.5	8.73
So. Ukraine 3	1000	935	10,552	13	15	60%	0.59	0	2.5	8.73
Rovno 1	440	380	10,552	8	5	80%	0.65	0	2.6	9.46
Rovno 2	440	380	10,552	8	5	80%	0.65	0	2.6	9.46
Rovno 3	1000	930	10,552	13	15	60%	0.65	0	2.6	9.46
Khmelnitsky 1	1000	955	10,552	13	15	60%	0.65	0	2.6	9.46
Khmelnitsky 2	1000	955	10,552	13	10	65%	0.65	40	5.6	19.48
Rovno 4	1000	930	10,552	13	10	65%	0.65	40	5.6	19.48

Generating Plant Performance Comparison
Data as Used in Stone & Webster Study (After Kiev Data Conference)

Station	Capacity		Full Load	Outage Rates		Availability	Fuel Price	O & M Costs		Energy Cost @
	Rated	Operating	Heat Rate (KJ/kwh)	Sch.Maint. (Weeks)	Forced (%)	Net (%)	($/GJ)	Fixed ($/kw-yr)	Variable ($/MWh)	Max. Availability ($/MWh)
Fossil										
Burshtyn 5-12	1520	1383	9,700	9	13.5	69%	1.85	15.00	6.40	26.82
Kurakhov	1470	1338	9,842	9	13.5	69%	1.67	16.00	6.10	25.17
Ladizhin	1800	1638	9,573	9	13.5	69%	2.12	12.10	5.50	27.79
Zuev	1200	1092	9,240	9	13.5	69%	1.67	12.60	5.50	23.01
Krivorozn 2-3	600	564	9,738	9	20.8	62%	1.67	12.40	5.90	24.45
Krivorozn 5-6	600	564	9,738	9	20.8	62%	1.67	12.40	5.90	24.45
Krivorozn 7-10	1200	1128	9,738	9	20.8	62%	1.67	12.40	5.90	24.45
Lugansk 12-15	800	728	11,142	9	13.5	69%	2.12	15.90	7.00	33.24
Pridniprov 11-14	1140	1037	9,940	9	13.5	69%	1.85	15.90	6.60	27.61
Slavyansk 1	720	720	9,941	9	20.8	62%	2.65	11.70	7.50	36.00
Staobeshevo 4	200	210	9,875	6	7.0	81%	0.74	17.00	7.00	16.69
Starobeshevo 5-13	1800	1593	10,400	9	23.2	60%	1.85	15.80	7.00	29.27
Tripoli 1-4	1200	1200	9,522	9	20.8	62%	1.85	12.30	5.50	25.38
Tripoli 5-6	600	561	8,870	9	15.6	67%	2.82	14.60	7.00	34.50
Zmiev 7-10	1200	1100	9,593	9	14.1	69%	1.85	13.40	7.50	27.47
Zmiev 2,4,6	600	478	10,568	9	13.4	69%	1.85	15.40	7.00	29.09
Uglegorsk 1-4	1200	1092	9,163	9	13.5	69%	1.67	12.60	5.50	22.88
Uglegorsk 5-7	2400	2400	8,786	9	20.8	62%	2.82	11.70	7.50	34.43
Zaporozhe 1-4	1200	1092	8,973	9	13.5	69%	1.85	12.60	5.50	24.18
Zaporozhe 5-7	2400	2400	8,873	9	20.8	62%	2.65	8.30	5.50	30.54
CHP	3000	2910	11,996	7	19.3	67%	2.65	32.90	15.20	52.57
Kharkov 1-2	206	206	11,996	4	26.5	66%	2.65	20.70	6.20	41.58
Kharkov 3	250	250	10,281	4	29.6	63%	2.65	14.70	6.70	36.62
Kiev/5 1-2	200	188	11,920	4	25.1	67%	2.70	19.60	6.70	42.21
Kiev/5 3-4	500	500	10,265	4	29.6	63%	2.70	14.80	6.70	37.11
Kiev/6 1-2	500	500	10,265	4	29.6	63%	2.70	14.80	6.70	37.11
Composite	28,506	26,872	9,352			66%	2.28			31.30
Nuclear										
Zaporozhe 1	1000	950	11,000	9	9.6	73%	0.70	30	2.6	14.99
Zaporozhe 2	1000	950	11,000	9	9.6	73%	0.70	30	2.6	14.99
Zaporozhe 3	1000	950	11,000	9	9.6	73%	0.70	30	2.6	14.99
Zaporozhe 4	1000	950	11,000	9	9.6	73%	0.70	30	2.6	14.99
Zaporozhe 5	1000	950	11,000	9	9.6	73%	0.70	30	2.6	14.99
Zaporozhe 6	1000	950	11,000	9	9.6	73%	0.70	30	2.6	14.99
So. Ukraine 1	1000	950	11,000	9	9.6	73%	0.70	30	2.6	14.99
So. Ukraine 2	1000	950	11,000	9	9.6	73%	0.70	30	2.6	14.99
So. Ukraine 3	1000	950	11,000	9	9.6	73%	0.70	30	2.6	14.99
Rovno 1	402	361	11,000	8	2	83%	0.70	30	2.6	14.45
Rovno 2	416	384	11,000	8	2	83%	0.70	30	2.6	14.45
Rovno 3	1000	950	11,000	9	9.6	73%	0.70	30	2.6	14.99
Khmelnitsky 1	1000	950	11,000	9	9.6	73%	0.70	30	2.6	14.99
Khmelnitsky 2	1000	950	11,000	9	9.6	73%	0.70	30	2.6	14.99
Rovno 4	1000	950	11,000	9	9.6	73%	0.70	30	2.6	14.99

APPENDIX E

Plant Additions for Base Case Scenario

UKRAINE
K2/R4 Completion Due Diligence
Least-cost Planning Analysis

Plant Additions for Base Case Scenario

Year	Plant Addition
2000	
2001	
2002	Khmelnitsky 2
	Rovno 4
2003	
2004	4 X 300 MW High Level Rehabilitation
2005	4 X 300 MW High Level Rehabilitation
2006	2 X 300 MW High Level Rehabilitation
	2 X 300 MW Low Level Rehabilitation
2007	2 X 300 MW Low Level Rehabilitation
2008	4 X 200 MW High Level Rehabilitation
2009	4 X 200 MW High Level Rehabilitation
2010	2 X 200 MW High Level Rehabilitation
	4 X 200 MW Low Level Rehabilitation