

REPORT BY THE U.S.

General Accounting Office

9514

Tennessee Valley Authority Can Improve Estimates And Should Reassess Reserve Requirements For Nuclear Power Plants

Cost estimates for Hartsville, Phipps Bend, and Yellow Creek nuclear powerplants are understated several hundred million dollars each, because of excluded costs and optimistic and probably unachievable construction schedules. GAO recommends that cost and schedule estimates for the plants be adjusted to reflect the best assessment of what actual results will be.

Since 1974, forecasts of demands for electricity during the 1980s have decreased steadily and significantly. Generating capacity requirements which are based on the demand forecasts include a reserve factor of about 30 percent, which is equal to about one-third to one-half of the generating capacity to be provided by the Tennessee Valley Authority's seven nuclear plants. In view of the trend of demand forecasts, we recommend that the Board of Directors reassess the reserve requirements.



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UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

ENERGY AND MINERALS
DIVISION

B-114850

Mr. S. David Freeman
Chairman, Board of Directors
Tennessee Valley Authority

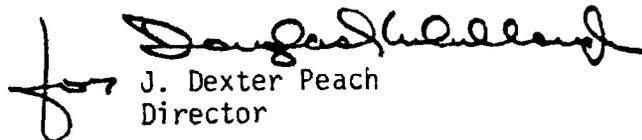
Dear Mr. Freeman:

This report summarizes the results of our review of the Hartsville, Phipps Bend, and Yellow Creek nuclear power plants.

This report contains recommendations to you on pages 18, 21, and 25. As you know, section 236 of the Legislative Reorganization Act of 1970 requires the head of a Federal agency to submit a written statement on actions taken on our recommendations to the Senate Committee on Governmental Affairs and the House Committee on Government Operations not later than 60 days after the date of the report and to the House and Senate Committees on Appropriations with the agency's first request for appropriations made more than 60 days after the date of the report.

We are sending copies of this report to the Director, Office of Management and Budget.

Sincerely yours,


for J. Dexter Peach
Director



GENERAL ACCOUNTING OFFICE
REPORT TO THE CHAIRMAN OF
THE BOARD, TENNESSEE
VALLEY AUTHORITY

TENNESSEE VALLEY AUTHORITY CAN
IMPROVE ESTIMATES AND SHOULD
REASSESS RESERVE REQUIREMENTS
FOR NUCLEAR POWER PLANTS

D I G E S T

The Tennessee Valley Authority (TVA) has based its significant commitment to nuclear power on studies indicating that nuclear powerplants represent the best short-range assurance of an adequate supply of electricity, in an environmentally acceptable manner, at the lowest possible rates. In 1978 the Authority was operating one nuclear powerplant and constructing six others, including plants at Hartsville--the world's largest--Phipps Bend, and Yellow Creek. When completed during the latter half of the 1980s, the seven plants will generate about 20,245 megawatts of electricity, which will represent about 45 percent of TVA's total generating capacity of 44,440 megawatts at that time. By the late 1980s, TVA believes it will need additional generating capacity, and has plans for two more 1,200 megawatt generating units. It has not decided where or when the units will be constructed or whether they will be nuclear, coal, or some other alternative. (See pp. 1 and 2.)

COST AND SCHEDULE CHANGES

As of September 1978, TVA estimated that construction costs of the Hartsville plant increased about \$2.1 billion. For Yellow Creek and Phipps Bend, the Authority estimated construction costs increased about \$.5 billion and \$.2 billion, respectively. Commercial operations have been delayed by 50 months for Hartsville, 28 months for Phipps Bend, and 25 months for Yellow Creek. (See p. 5.)

GAO found that TVA's current cost estimates of September 30, 1978, for the three plants are understated by several hundred million dollars each.

Both cost increases and schedule changes are attributable to the tentative nature of the original estimates and to factors such as escalating wage rates, inflation, changes in scope and design, and schedule delays and extensions. (See pp. 6 and 7.)

Current cost estimates do not include estimated costs of an added 9-month contingency period, which increased the estimated costs of Hartsville by \$400 million, Phipps Bend by \$200 million, and Yellow Creek by \$250 million. Costs for interest and contingency factors were particularly increased by the 9-month stretchout of the construction period. (See p. 10.)

Current estimates exclude costs for overtime work. TVA's estimating procedures provide for an overtime allowance of from 3 to 5 percent, and, according to construction officials, experience indicates an actual rate of from 5 to 7 percent. At 5 percent, overtime costs would increase estimates for Hartsville, Phipps Bend, and Yellow Creek by \$15.2 million, \$8.2 million, and \$12.2 million, respectively. (See p. 12.)

Late receipt of the limited work authorization from the Nuclear Regulatory Commission delayed construction at Phipps Bend by about 4 months--from July 1 to October 18, 1977. TVA has not developed estimates for determining the extent to which schedule stretchouts will increase overall costs. (See p. 12.)

Current cost estimates are based on completing the first reactor units at Hartsville, Phipps Bend, and Yellow Creek in 79 months, 75 months, and 81 months, respectively. (See p. 13.) TVA's own experience and analyses, as well as experience of private utility companies, in-

dicade that the schedule will probably have to be stretched out 1 to 2 years. (See p. 14.)

ESTIMATES USED FOR EVALUATING ALTERNATIVE POWER SOURCES

TVA has used the understated cost and schedule estimates in showing that nuclear-fired facilities at Hartsville, Phipps Bend, and Yellow Creek are substantially more cost effective than coal-fired facilities. GAO's review indicated that the estimating errors are not of sufficient magnitude to offset the cost advantages calculated for nuclear facilities. For example, current estimates for nuclear facilities at Hartsville, Phipps Bend, and Yellow Creek would have to increase by \$2,950 million, \$1,460 million, and \$1,154 million, respectively, to equal the cost of coal facilities for the first 10 years of operations. After 10 years, the equalizing increase required would be even greater. (See p. 19.)

In evaluating the cost effectiveness of coal-fired plants, TVA has been using cost estimates based largely on previous construction experience. However, because recent evaluations indicate that the cost advantage of nuclear plants is decreasing, the Authority plans to obtain industry price quotations on major components of coal-fired facilities in making the next cost-effectiveness evaluation. (See p. 20.)

GENERATING CAPACITY

TVA's forecasts of demands for electricity during the 1980s, combined with desired reserve generating capacity, show a need for a total generating capacity in excess of the 44,440 megawatts to be provided by powerplants now operating and under construction. However, since 1974, forecasts of demands have decreased steadily and significantly. For example, from 1974 to

1977, the forecasted peak-winter demand in 1985 decreased from 39,800 to 34,300 megawatts. Likewise, generating requirements, including reserve capacity, decreased from 46,269 to 42,562 megawatts. Although an official forecast has not been adopted for 1978, each of four options submitted to management reflects further decreases in both demands and generating requirements.

Generating capacity requirements include reserves to meet demands when some plants are shutdown. TVA's forecasts reflect desired reserve generating capacities of up to 30 percent of forecasted demands. For example, the forecast recommended for 1978 reflects requirements for reserve generating capacity ranging from 6,354 megawatts during the winter of 1980 to 10,324 megawatts during the winter of 1990. The latter amount is equal to about one-third to one-half of the generating capacity to be provided by the Authority's seven nuclear plants. (See p. 23.)

AGENCY COMMENTS

TVA officials acknowledged that the cost and schedule estimates for Hartsville, Phipps Bend, and Yellow Creek are understated. They said that the estimates have been deliberately kept low to establish tight goals for the construction staff. However, they also indicated that differences in facility design, safety and environmental requirements, and site features from plant to plant have prevented development of reliable estimates. They said that by the spring of 1979 they hope to complete actions intended to improve the accuracy of cost and schedule estimates. The officials also said that the Authority is developing a system of preparing and monitoring cost estimates, which is closely tied to its system of assessing productivity.

TVA officials also said that they are contacting consultants to review and appraise the Authority's reserve planning methodology.

RECOMMENDATIONS

GAO recommends that TVA base estimates for powerplants on likely cost and schedule conditions. GAO also recommends that cost and schedule estimates for Hartsville, Phipps Bend, and Yellow Creek be adjusted to reflect the best assessment of what actual results will be. For future cost effectiveness evaluations of nuclear and coal-fired powerplants, GAO recommends that TVA use cost and schedule estimates which, to the best of its knowledge and ability, reflect the results and trends of its own experience and analyses, as well as that of private utility companies.

In view of the large amount of reserve capacity and the trend of demand forecasts, we are also recommending that the Board of Directors reassess the reserve requirements.



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ABBREVIATIONS

GAO	General Accounting Office
NRC	Nuclear Regulatory Commission
TVA	Tennessee Valley Authority



CHAPTER 1

INTRODUCTION

Electricity generated by the Tennessee Valley Authority (TVA) supplies the needs of an 80,000 square mile area with a population of 6.4 million people. The area covers most of Tennessee, portions of southeastern Kentucky, northeastern Mississippi, northern Alabama, northern Georgia; and small sections of North Carolina and Virginia. In 1977 TVA supplied electricity directly to 160 municipal and cooperative electric systems (49 large, private industries and several Federal nuclear, aerospace, and military agencies).

TVA'S NUCLEAR POWER PROGRAM

TVA based its commitment to nuclear power on studies indicating that nuclear plants represent the best short-range assurance of an adequate supply of electricity, in an environmentally acceptable manner, at the lowest possible rates.

In 1978 the Authority was operating one nuclear plant and constructing six others, as shown by the following table.

<u>Plant (units)</u>	<u>Location (near)</u>	<u>Megawatts (1 million watts) generated</u>		<u>Scheduled operating date of last unit</u>	
		<u>Maximum</u>	<u>Dependable</u>		
Browns Ferry (3)	Decatur, Ala.	3,456	3,201	Mar.	1977
Sequoyah (2)	Chattanooga, Tenn.	2,442	2,296	May	1979
Watts Bar (2)	Spring City, Tenn.	2,540	2,354	Mar.	1981
Bellefonte (2)	Scottsboro, Ala.	2,664	2,426	June	1982
Hartsville (4)	Hartsville, Tenn.	5,148	4,932	Dec.	1984
Phipps Bend (2)	Surgoinsville, Tenn.	2,574	2,466	Aug.	1985
Yellow Creek (2)	Corinth, Miss.	2,750	2,570	May	1986
		<u>21,574</u>	<u>20,245</u>		

TVA is evaluating the need for two additional 1,200 megawatt power generating units, but has not decided where or when the units will be constructed or whether the units will be nuclear, coal, or some other alternative.

During 1978 the Authority had a maximum dependable generating capacity of about 26,096 megawatts of electricity from 47 hydroelectric plants, 12 coal-fired plants, 4 combustion-turbine plants, and 1 nuclear plant. When the other six nuclear plants are completed, TVA will have a maximum

dependable generating capacity of about 44,440 megawatts of electricity. The dependable capacity of 20,245 megawatts generated by the seven nuclear plants will represent about 46 percent of this total.

STATUS OF HARTSVILLE, PHIPPS BEND,
AND YELLOW CREEK PLANTS

Construction of the Hartsville, Phipps Bend, and Yellow Creek plants started in April 1976, October 1977, and February 1978, respectively.

TVA estimates that overall construction at Hartsville is about 14-percent complete. Excavation for permanent facilities is 70-percent complete, construction of reactor buildings is about 5-percent complete, and construction of turbine buildings is about 8-percent complete. Switchyard completion ranges from 2 percent for two generating units to 19 percent for the other two generating units.

Overall construction at Phipps Bend is estimated to be about 4-percent complete. Excavation for permanent facilities is about 27-percent complete, earth and rock excavation for circulating water lines is in progress, placement of reinforcing steel for the first reactor building base is in progress, and switchyard grading is nearing completion.

At Yellow Creek, overall construction is estimated to be about 3-percent complete. Completion of construction-support facilities ranges from 30 to 68 percent. Primary effort on the permanent plant consists of pipe installation in the turbine buildings and rock excavation for the reactor buildings.

CONSTRUCTION OF NUCLEAR
POWER PLANTS

Planning, licensing, and constructing nuclear power-plants takes from 10 to 12 years. In recent years the Nuclear Regulatory Commission (NRC) has changed several administrative practices and has proposed changes in its legislative authority in an attempt to decrease the leadtime for acquiring nuclear plants. The administrative changes include:

- Authorizing limited construction work after completion of public hearings on environmental and site suitability considerations.

--Encouraging development and use of standard nuclear powerplant designs.

--Allowing utility companies to seek advance review and approval of potential construction sites.

The legislative changes are intended to improve the licensing process by (1) permitting earlier site approvals, (2) standardizing plant designs, (3) clearly delineating the respective roles of Federal and State regulators, and (4) modifying public participation.

PRIOR REPORTS

On March 1, 1976, we issued a staff study on the Bellefonte Nuclear Plant (PSAD-76-86) and reported that TVA's 1975 demand forecast projected a lesser increase in demand than the prior year demand forecast.

We reported to the Congress in "Reducing Nuclear Power Plant Leadtime: Many Obstacles Remain," (EMD-77-15), March 2, 1977, and "Nuclear Powerplant Licensing: Need for Additional Improvements," (EMD-78-29), April 27, 1978, that prospects were not good for significantly decreasing the leadtime for nuclear plants. Obstacles to decreasing the leadtime included:

--Growing State and local government requirements.

--Growing public concern.

--Changes resulting from court decisions invalidating NRC regulations.

--Changes resulting from technological advances and operating experience.

In a November 29, 1978, report to the Congress, entitled "Electric Energy Options Hold Great Promise for the Tennessee Valley Authority," (EMD-79-91), we assessed TVA's energy related problems in terms of national policies related to demand management and other matters. We reported that the data used for demand projections was inadequate, both for TVA and our projections.

FINANCIAL SUPPORT

TVA funds its electric power program from power revenues and borrowings. For fiscal year 1978, the power program budget was about \$3.6 billion, including about \$1.6 billion for capital outlays. In 1978 the Authority was estimating that capital costs for its seven nuclear plants would be about \$11.8 billion.

The Congress has authorized TVA to incur an indebtedness of up to \$15 billion to finance its power program. As of September 30, 1978, the Authority had an outstanding indebtedness of \$7.2 billion from bond and note sales, U.S. Treasury advances, and Federal Finance Bank loans. However, the indebtedness is neither an obligation of, nor guaranteed by, the Federal Government.

SCOPE OF REVIEW

We reviewed TVA's policies, procedures, and practices for developing cost and schedule estimates and its working papers, correspondence, reports, and studies relating to cost and schedule estimates. We also reviewed projected requirements for electrical power and comparisons of the construction and operating costs of nuclear- and coal-fired plants. Additionally, we interviewed Authority and NRC officials.

We conducted the review at TVA's offices in Knoxville and Chattanooga, Tennessee; NRC's office in Bethesda, Maryland; and the Hartsville nuclear plant construction site in Hartsville, Tennessee.

CHAPTER 2

COST AND SCHEDULE ESTIMATES HAVE BEEN IMPROVED

BUT CONTINUE TO BE UNDERESTIMATED

TVA estimated that costs for acquiring the Hartsville, Phipps Bend, and Yellow Creek nuclear powerplants have increased significantly since TVA first proposed the projects to the Congress.

Estimated Costs

	<u>Original</u>	<u>Current</u>	<u>Increase</u>	
	<u>Date</u>	<u>Amount</u>	<u>September 1978</u>	
		(millions)		
Hartsville	Jan. 1972	\$1,425	\$3,500	\$2,075
Phipps Bend	Jan. 1975	1,600	1,800	200
Yellow Creek	Jan. 1975	1,900	2,400	500

Commercial operations have also been delayed by 50 months for Hartsville, 28 months for Phipps Bend, and 25 months for Yellow Creek, respectively. Based on information obtained from TVA, we believe that the current estimates for each plant are understated by at least several hundred million dollars. The estimates do not include costs for overtime work and some schedule adjustments. Also, amounts allocated for contingencies and interest are less than those calculated by cost and estimating personnel. The Authority also based the estimates on construction schedules which are more optimistic than justified by its own experience or that of private utility companies.

As a result, it is inappropriate to use the cost and schedule estimates for long-range planning or for evaluating the efficiency of construction operations. TVA officials said that the estimates have been kept optimistic to establish tight goals for the construction staff, but that continuing changes in facility designs, safety, and environmental requirements, and differences in site features from plant to plant have prevented the development of reliable estimates. The officials also said that private utility companies have experienced similar estimating problems.

We agree that a number of factors have made it difficult to develop accurate cost and schedule estimates for nuclear powerplants. However, we believe that TVA's own experience and analyses, as well as experience of private utility companies, provides an improved basis for developing estimates that are much more realistic and reliable.

CHANGES IN COST AND SCHEDULE ESTIMATES

Some of the cost increases and schedule changes can be attributed to the preliminary nature of the original estimates, which were prepared before TVA had selected the types and locations of the plants. Also, when the Authority proposed the original estimates for the three plants, it had very limited experience in constructing nuclear plants to draw upon. For example, when it prepared cost and schedule estimates for Hartsville in 1971, construction of the Browns Ferry and Sequoyah plants was in progress, but no generating units had been completed. Similarly, when it prepared estimates for Phipps Bend and Yellow Creek in 1974, construction of the Watts Bar plant was also in progress, but only the first reactor unit at Browns Ferry had been completed. However, the tentative nature of TVA's original figures and its limited experience only partially account for the subsequent increases and changes in cost and schedule estimates.

Cost increases

TVA officials cite escalating wage rates, inflation, changes in scope and design, and schedule delays and extensions as major factors contributing to higher cost estimates. Although changes and differences in methods used to develop and present estimates do not permit a completely accurate categorization of the increases, we allocated the cost increases for various causes, as follows:

<u>Causes</u>	<u>Cost increase</u>		
	<u>Hartsville</u>	<u>Phipps Bend</u>	<u>Yellow Creek</u>
	<u>(millions)</u>		
Increased field labor for changes in scope, design revisions, schedule changes, and escalating wage rates	\$ 280.4	\$ 58.0	\$171.6
Increased materials and equipment for changes in scope, design revisions, escalation, and extended use of construction facilities	763.3	52.5	38.4
Provisions for added engineering quality assurance, field supervision, construction support requirements, and socioeconomic impact mitigation	249.4	48.9	123.7
Interest for higher costs and longer schedules	573.0	50.0	155.0
Contingencies	<u>208.9</u>	<u>-9.4</u>	<u>11.3</u>
Total	<u>\$2,075.0</u>	<u>\$200.0</u>	<u>\$500.0</u>

Schedule changes

TVA had to extend schedules for achieving commercial operation at the three plants by as much as 4 years, as the following indicates:

<u>Plant</u>	<u>Estimated commercial operation date</u>		<u>Change in months</u>
	<u>Original</u>	<u>Current</u>	
Hartsville:			
Reactor unit 1	4/79	6/83	50
Reactor unit 2	4/80	6/84	50
Reactor unit 3	10/79	12/83	50
Reactor unit 4	10/80	12/84	50
Phipps Bend:			
Reactor unit 1	4/82	8/84	28
Reactor unit 2	4/83	8/85	28
Yellow Creek:			
Reactor unit 1	4/83	5/85	25
Reactor unit 2	4/84	5/86	25

Changes in the schedules have resulted both from delays in receiving construction permits from NRC and from extensions in the estimated length of time required for construction. TVA attributes the changes to the following causes:

<u>Cause</u>	<u>Schedule changes</u>		
	<u>Hartsville</u>	<u>Phipps Bend</u>	<u>Yellow Creek</u>
	------(months)-----		
Delays in construction permits:			
Late award of contract for nuclear supply system	5-1/2		
Late submission of preliminary safety analysis report and environmental statement to NRC	9-1/2		4
Late completion of project review by the NRC	10	15	6
Subtotal	25	15	10
Extension of construction period:			
Moratorium on permanent construction by NRC	4		
Construction period for first unit lengthened to provide for more realistic schedules	12	4	
Construction period lengthened to provide time for additional site preparation work			6
Contingency to provide for possible unforeseen delays in construction	9	9	9
Subtotal	25	13	15
Total	50	28	25

Delays in construction permits

NRC must issue a construction permit--a "limited work authorization"--before construction on a nuclear powerplant can begin. Late receipt of the authorization caused delays at Hartsville, Phipps Bend, and Yellow Creek, as shown below:

Delays in starting construction

	<u>Original schedule</u>	<u>Actual</u>	<u>Difference (months)</u>
Hartsville	4/1/74	4/26/76	25
Phipps Bend	8/1/76	10/19/77	15
Yellow Creek	4/1/77	2/13/78	10

TVA attributes most of the delays to NRC's documentation and review requirements. For example, according to the Authority, it had to extend preparing the preliminary safety analysis report and environmental statement for the Hartsville plant by 9-1/2 months, primarily because of new requirements from NRC. TVA also attributed delays of 10 months at Hartsville, 15 months at Phipps Bend, and 6 months at Yellow Creek to NRC's late completion of project reviews, which include evaluation of the safety analysis, environmental reports, and public hearings.

Extensions in construction period

TVA also lengthened the schedule for Hartsville, Phipps Bend, and Yellow Creek to accommodate changes in the estimated length of time required for construction. Revised schedule milestones for the first reactor units reflect the changes.

<u>Plants</u>	<u>Schedule</u>	<u>Begin construction</u>	<u>Commercial operations</u>	<u>Construction time (months)</u>
Hartsville	Original	4/1/74	4/1/79	60
	Current	4/26/76	6/1/83	85
Phipps Bend	Original	8/1/76	4/1/82	68
	Current	10/19/77	8/1/84	81
Yellow Creek	Original	4/1/77	4/1/83	72
	Current	2/13/78	5/1/85	87

TVA lengthened the construction periods, primarily to establish more realistic schedules. However, in the case of Hartsville, a construction moratorium imposed by NRC added 4 of the 25 months to the schedule. NRC called a halt to pouring concrete for permanent plant construction at the Hartsville plant from August 31 to December 27, 1976, while it reviewed a Federal court decision concerning its environmental reviews.

UNDERSTATEMENTS IN COST
AND SCHEDULE ESTIMATES

Information obtained from TVA points to the likelihood that the current cost estimates of \$3.5 billion for Hartsville, \$1.8 billion for Phipps Bend, and \$2.4 billion for Yellow Creek will increase significantly, because these estimates do not include certain significant costs and are based on highly optimistic construction schedules.

Current cost estimates for Hartsville, Phipps Bend, and Yellow Creek do not include amounts for the 9-month contingency period added to construction schedules in 1976, and the estimate for Phipps Bend does not include an amount for the 4-month delay in starting construction. Also, none of the estimates include provisions for overtime work.

Nine-month contingency period

In 1977 TVA's estimating personnel developed revised estimates of \$3.9 billion for Hartsville, an increase of \$400 million; \$2.0 billion for Phipps Bend, an increase of \$200 million; and \$2.4 billion for Yellow Creek, an increase of \$250 million. (See table on p. 11.) These estimates contained increases in costs of materials and equipment, general expenses, interest, and contingencies. Officials attributed the increases primarily to inflation and to changes in scope and design. Costs for interest and contingencies particularly increased, because the added 9-month contingency period resulted in a longer construction period. TVA officials said that labor costs for the contingency period were not estimated because of uncertainties about when, where, and for what reason it would be used.

When the revised estimates were presented to TVA's top management, they decided to delete costs for the additional 9 months to minimize costs for other contingencies and to otherwise maintain the estimates at levels comparable to internal estimates made in 1976. According to officials of TVA's Office of Engineering Design and Construction, management took this action because reliable information was not available to estimate the total cost of the extended schedule. However, the officials agreed that the 9 months would be needed for construction and would increase labor, interest, and other costs.

The following table shows the adjustments made by management to arrive at the estimates, current as of January 1978. Coincidentally, the September 1978 estimate for Yellow Creek includes an increase of \$250 million. However, the increase is for increased manhours and design and support costs etc. It is not related to the 9-month schedule contingency or to the other adjustments made by management in 1977.

<u>Cost element</u>	<u>Estimate by estimating personnel</u>	<u>Adjustments</u>	<u>January 1978 estimate</u>
	(millions)		
<u>Hartsville</u>			
Field labor	\$ 607.7	-	\$ 607.7
Material and equipment	1,400.0	\$ 28.4	1,428.4
General expenses	396.9	-28.7	368.2
Interest	1,000.0	-215.0	785.0
Contingencies	<u>495.4</u>	<u>-184.7</u>	<u>310.7</u>
Total	<u>\$3,900.0</u>	<u>-\$400.0</u>	<u>\$3,500.0</u>
<u>Phipps Bend</u>			
Field labor	\$ 328.0	-	\$ 328.0
Material and equipment	740.0	\$ 22.5	762.5
General expenses	196.4	-12.8	183.6
Interest	505.0	-135.0	370.0
Contingencies	<u>230.6</u>	<u>-74.7</u>	<u>155.9</u>
Total	<u>\$2,000.0</u>	<u>-\$200.0</u>	<u>\$1,800.0</u>
<u>Yellow Creek</u>			
Field labor	\$ 382.0	-	\$ 382.0
Material and equipment	860.0	\$ 14.2	874.2
General expenses	251.4	-13.2	238.2
Interest	570.0	-120.0	450.0
Contingencies	<u>336.6</u>	<u>-131.0</u>	<u>205.6</u>
Total	<u>\$2,400.0</u>	<u>-\$250.0</u>	<u>\$2,150.0</u>

Overtime

Current estimates for Hartsville, Phipps Bend, and Yellow Creek also exclude costs for overtime work. Estimating procedures provide for an overtime allowance of from 3 to 5 percent of regular-time costs. According to construction officials, experience indicates an actual overtime rate of from 5 to 7 percent. At 5 percent, overtime costs would increase estimates for Hartsville, Phipps Bend, and Yellow Creek by about \$15.2 million, \$8.2 million, and \$12.2 million, respectively.

Construction delay

A delay of about 4 months in receiving the limited work authorization from NRC will further add to costs for the Phipps Bend project. TVA personnel based the current estimates for Phipps Bend on receipt of the limited work authorization by July 1, 1977. However, it did not arrive until October 18, 1977, and construction could not begin until it did. The Authority's estimating personnel have not calculated the cost of this delay.

Optimistic construction schedules

TVA's estimates of the time required to construct the Hartsville, Phipps Bend, and Yellow Creek powerplants appear to be understated by at least 1 to 2 years. The extent to which schedule stretchouts will add to costs were not determined, but schedule extensions of that magnitude will undoubtedly increase costs for items such as labor, equipment, and interest.

Estimated schedules

Schedules as of September 1978 for construction and commercial operations, including the 9-month schedule contingency in construction, are as follows:

Schedule From Construction Start

<u>Reactor unit</u>	<u>Construction</u>			<u>Commercial operations</u>	
	<u>Start</u>	<u>Complete</u>	<u>Months</u>	<u>Date</u>	<u>Months</u>
<u>Hartsville</u>					
1	4/26/76	12/82	79	6/83	85
2	4/26/76	12/83	91	6/84	97
3	4/26/76	6/83	85	12/83	91
4	4/26/76	6/84	97	12/84	103
<u>Phipps Bend</u>					
1	10/19/77	2/84	75	8/84	81
2	10/19/77	2/85	87	8/85	93
<u>Yellow Creek</u>					
1	2/13/78	11/84	81	5/85	87
2	2/13/78	11/85	93	5/86	99

TVA added the 9-month period to schedules for fuel loading, but it was and is expected to be used for construction.

Critical milestones

Dates for completing construction of the first reactor units are critical milestones in the overall schedule for each plant, because subsequent milestones are derived from and generally dependent on meeting those dates. Any change in the time required to construct the first units will cause comparable changes in the milestones for other units and for achieving commercial operation.

Bases for schedule estimates

Estimates of the time required to complete construction of the first reactor units--79 months at Hartsville, 75 months at Phipps Bend, and 81 months at Yellow Creek--presume near-optimum construction progress. TVA developed the times using a base of 66 months, which it viewed as a minimum construction period theoretically achievable under optimum conditions: that is, without disruptions caused by such factors as inclement weather; labor shortages; scheduling difficulties; regulatory changes; design changes; and delays in receiving supplies,

material, and equipment. The Authority did adjust the base period to accommodate plant facilities, equipment, and conditions peculiar to individual sites. TVA also increased the base period by 9 months, from 66 months to 75 months, based on an analysis completed in April 1976 which indicated that the additional months would increase from 14 to 50 percent the probability of completing the first reactor units on schedule. However, this same 1976 analysis indicated that to achieve a 95-percent probability of completing construction on schedule, TVA would have to increase the base period by an additional 17 months, for a total of 92 months. More recently, in June 1978, the Authority's construction staff recommended that the basic schedules for constructing first reactor units be increased to 84 months. In July 1978 the scheduling personnel recommended an 80-month schedule-- increases of 18 and 14 months, respectively, over the base schedule. Based on evaluations of the average construction time experienced in the industry, both staffs considered their recommended schedules realistic when coupled with the previously added 9-month contingency.

Construction experience

TVA's own experience and analyses, as well as the experience of private utility companies, indicate very little likelihood that the first reactor units at Hartsville, Phipps Bend, and Yellow Creek can be completed within current schedules of less than 7 years. The Authority will probably have to extend the schedules 1 to 2 years.

Through calendar year 1977, private utility companies required from 21.9 months to construct a 63-megawatt reactor unit completed in 1962, to 106.6 months for a 1,084-megawatt unit completed in 1977. The steady increase in average time needed to complete construction of privately owned reactor units can be seen from the following table:

<u>Calendar year</u>	<u>Number of reactor units</u>	<u>Average construction duration for first units</u>
Before 1970	12	46.0 months
1970	4	47.6 months
1971	4	54.9 months
1972	5	66.0 months
1973	7	68.0 months
1974	10	66.9 months
1975	3	78.7 months
1976	4	91.4 months
1977	4	90.4 months

For four reactor units either completed or scheduled for completion in 1978, the estimated average construction time is 92.3 months, based on a low of 82 months for a 912-megawatt unit, to a high of 107 months for a 906-megawatt unit.

TVA's limited experience has been similar to that of private utility companies. As of August 1978, the Authority had completed reactor units at only the Browns Ferry plant. Fuel was loaded in the first unit at this plant in June 1973 after a construction period of about 82 months. The first unit at TVA's second plant, Sequoyah, is scheduled for fuel loading in April 1979, after a construction period of about 120 months. The Authority does not consider the Sequoyah time typical, because rework to satisfy new NRC requirements has extended the construction time. However, the Sequoyah experience is consistent with trends in private industry.

ESTIMATES UNSATISFACTORY FOR
MANAGEMENT PURPOSES

Since the current cost and schedule estimates for Hartsville, Phipps Bend, and Yellow Creek are understated by undetermined amounts, TVA officials cannot rely on them for planning 5 to 10 years hence or for evaluating the efficiency of construction operations. For example, the estimates cannot be used for reliably projecting

--how much money will be needed,

--when the plants will be available to supply electricity,

--when and how much electricity will have to be bought from other suppliers, and

--how much consumers will have to pay for electricity.

Moreover, the estimates cannot be used to reliably project TVA's indebtedness in relation to limits on its borrowing authority.

As a result, TVA officials have made "what if" studies. For example, in 1978 the Authority studied the impact that changes in cost and schedule estimates for power program projects would have on funding needs, profits and losses, long-term and short-term indebtedness, and generated and purchased supplies of electricity through 1988. The studies used the following optimistic, probable, and conservative cost and schedule estimates for the six nuclear powerplants under construction:

	Estimates		
	Optimistic (note a)	Probable costs	Conservative
	(millions)		
Sequoyah	\$1,300	\$1,336	\$1,441
Watts Bar	1,264	1,299	1,415
Bellefonte	1,623	1,658	1,834
Hartsville	3,507	3,771	4,270
Phipps Bend	1,806	1,951	2,224
Yellow Creek	2,409	2,603	2,970
	Commercial operations--first unit		
Sequoyah	10/79	4/80	10/80
Watts Bar	6/80	12/80	6/81
Bellefonte	12/81	6/82	12/82
Hartsville	8/83	8/84	8/85
Phipps Bend	1/85	1/86	1/87
Yellow Creek	5/85	5/86	5/87

a/Generally, these estimates represent the current official cost and schedule estimates for the powerplants indicated.

Moreover, the studies indicate that long-term and short-term indebtednesses will exceed the limit of \$15 billion on

the Authority's borrowing authority in 1983, based on the optimistic and probable estimates, and, in 1984, on the conservative estimates. The studies also indicate that in 1988, long-term and short-term indebtednesses will reach \$25.7 billion, based on the optimistic estimates, \$27.3 billion based on the probable estimates, and \$28 billion based on the conservative estimates. TVA officials said that in 1979 they will ask the Congress to increase the borrowing limit to an amount yet to be determined.

TVA has a system for tracking construction progress and labor productivity against cost. This system uses man-hour and time estimates which are independent of the estimates discussed in this report, and is a useful tool for management purposes. Greater reliance on this system could improve the accuracy and adequacy of the Authority's nuclear plant construction estimates.

AGENCY ACTIONS

According to TVA officials, actions are underway to improve the accuracy of cost and schedule estimates for Hartsville, Phipps Bend, and Yellow Creek. They said that estimating, construction, and engineering personnel have been asked to make their most realistic assessments of the cost and schedule requirements of these plants and that the reviews should be completed in the spring of 1979. The officials also said that the Authority is developing a system of preparing and monitoring cost estimates which is closely tied to its system of assessing productivity.

CONCLUSIONS

Cost and schedule estimates for the Hartsville, Phipps Bend, and Yellow Creek nuclear powerplants have increased significantly since the projects were proposed to the Congress. Additional increases of at least several hundred million dollars can be expected in the future, because the cost estimates exclude certain costs and are based on highly optimistic construction schedules.

Thus, current estimates for these plants are unrealistic and cannot be relied on for long-range planning or for evaluating the efficiency of construction operations. TVA officials attribute the problem to a number of factors which they say have prevented the development of reliable estimates. However, they believe that the accuracy of the estimates will

be greatly improved by a project to be completed in the spring of 1979.

We agree that several factors have made it difficult to prepare accurate cost and schedule estimates for nuclear powerplants. However, we believe that the problem is partially attributable to using construction schedules which depend on optimum conditions for success and which management knows are highly optimistic and probably unachievable. Moreover, we believe that TVA's own experiences and analyses, as well as experiences of private utility companies, currently provide an improved basis for developing more realistic estimates.

RECOMMENDATIONS

We recommend that TVA base estimates for powerplants on likely cost and schedule conditions. We also recommend that the cost and schedule estimates for Hartsville, Phipps Bend, and Yellow Creek be adjusted to reflect the best assessment of what actual results will be.)

CHAPTER 3

SELECTION OF NUCLEAR

GENERATING FACILITIES

TVA based its decisions to build nuclear generating facilities at Hartsville, Phipps Bend, and Yellow Creek on evaluations which showed that:

- Nuclear and coal-fired facilities were the only viable and reasonable alternatives for generating the required amounts of electricity.
- Nuclear facilities were substantially more cost effective than coal-fired facilities, primarily because of lower fuel costs.

Recent reevaluations by TVA still show that nuclear facilities are substantially more cost effective than coal-fired facilities. They also indicate that current estimates for constructing nuclear facilities at the three plants would have to be increased by the following amounts to equal the cost of coal-fired facilities for the first 10 years of operations.

Investment required to equalize costs with coal facilities

<u>Plant</u>	<u>Current estimate</u>	<u>Equalizing increase</u>		<u>Total</u>
		<u>Amount</u>	<u>Percentage</u>	
	(millions)			(millions)
Hartsville	\$3,500	\$2,950	84.3	\$6,450
Phipps Bend	1,800	1,460	81.1	3,260
Yellow Creek	2,400	1,154	48.1	3,554

After 10 years, the equalizing increase required would be even greater.

Although we did not review TVA's evaluations of the relative cost effectiveness of nuclear and coal-fired facilities in detail, we did find that current estimates for constructing the Hartsville, Phipps Bend, and Yellow Creek nuclear plants are understated by several hundred million dollars. (See ch. 2.) However, the understatements are not of sufficient magnitude to offset the cost advantages calculated for nuclear facilities.

ALTERNATIVES CONSIDERED

TVA evaluated energy sources other than coal before deciding to use nuclear power for the generating facilities at Hartsville, Phipps Bend, and Yellow Creek. These included geothermal heat, natural gas, oil, and hydropower, all of which were rejected for the following reasons:

- Geothermal: research showed that no known geothermal resources existed in the TVA area and that the potential for this type of power was very low.
- Natural gas: curtailments, shortages, and end-use priorities eliminated natural gas as a reasonable energy source; companies contacted could not supply required quantities.
- Oil: problems with foreign supplies and increasing prices made oil an unrealistic source.
- Hydropower: given the quantities of electricity needed, hydropower was not feasible, because most suitable sites for hydropower plants were already being used.

COMPARISON OF NUCLEAR AND COAL-FIRED FACILITIES

Coal was another alternative considered, but TVA's evaluations have shown that nuclear facilities being built at Hartsville, Phipps Bend, and Yellow Creek are substantially more cost effective than coal-fired facilities.

Construction costs for nuclear plants are greater than those for coal-fired plants. However, within 10 years, because of higher fuel and operation and maintenance costs, the situation reverses for overall costs. Assuming no changes in other costs, construction expenses for the Hartsville, Phipps Bend, and Yellow Creek plants would have to exceed September 1978 estimates by \$2,950 million, \$1,460 million, and \$1,154 million, respectively, before they equal 10-year costs for comparable coal-fired plants.

FUTURE EVALUATIONS

In evaluating the cost effectiveness of coal-fired plants, TVA has used cost estimates based largely on previous construction experience; it completed its last coal-fired

plant in 1973. However, for the next evaluation, the Authority plans to obtain industry quotations on major components, because the cost advantage of nuclear plants appears to be decreasing, as the following table illustrates.

Estimated
Construction And Operating Costs For
10-Year Period (mills-per-kilowatt-hour)

<u>Date of evaluation</u>	<u>Nuclear</u>	<u>Coal</u>	<u>Difference</u>
<u>Phipps Bend</u>			
Aug. 1974	13.13	24.01	10.88
May 1977	18.60	28.10	9.50
Dec. 1977	19.80	28.50	8.70
<u>Yellow Creek</u>			
Aug. 1974	13.46	24.00	10.54
Dec. 1977	21.90	29.90	8.00

CONCLUSIONS

Although based on questionable cost estimates, TVA's evaluations indicated that nuclear facilities were a more cost-effective choice than coal-fired facilities for generating the electricity to be supplied by the Hartsville, Phipps Bend, and Yellow Creek powerplants. However, recent comparisons indicate that the cost advantage of nuclear facilities are decreasing. We believe that this establishes a clear need for TVA to base future selections of generating facilities on the best possible cost estimates for both nuclear and coal-fired facilities and for any other competitive alternatives. In our opinion, it is inappropriate to continue making cost effectiveness comparisons based on estimates which are known to be highly optimistic and most likely unachievable.

RECOMMENDATION

We recommend that TVA base future cost-effectiveness evaluations of nuclear and coal-fired powerplants on cost and schedule estimates which, to the best of its knowledge and ability, reflect the results and trends of its own experience and analyses, as well as that of private utility companies.

CHAPTER 4

TVA'S NEED FOR

GENERATING CAPACITY

Recent TVA forecasts indicate that electricity requirements during the 1980s will be less than previously expected, but continue to show a need for the generating capacity to be provided by the Hartsville, Phipps Bend, and Yellow Creek nuclear plants. In fact, the most recent estimates indicate that by 1989, the Authority will need an even greater generating capacity than will be available from plants now operating or under construction.

DEMAND AND CAPACITY FORECASTS

Each year TVA develops fairly detailed forecasts of future demands for electricity in the area served by its power system. The forecasts include predictions of seasonal--winter and summer--peak demands, which serve as a primary basis for determining requirements for generating facilities.

The following table shows how significantly TVA's forecasts of demands for electricity during the 1980s have decreased since plans were made for constructing the Hartsville, Phipps Bend, and Yellow Creek plants.

Forecasted Peak Winter Demand (megawatts)

<u>Year</u>	<u>1974 forecast</u>	<u>1975 forecast</u>	<u>1977 forecast</u>	<u>1978 forecasts (note a)</u>	
				<u>Low</u>	<u>High</u>
1980	29,650	28,300	25,350	23,293	23,835
1981	31,300	29,800	26,650	25,090	25,933
1982	33,100	31,250	28,100	26,916	28,100
1983	34,950	32,700	29,650	28,071	29,571
1984	37,100	34,650	31,700	29,796	31,672
1985	39,800	37,150	34,300	31,877	34,154
1986	41,650	38,900	36,000	33,030	35,671
1987	43,450	40,650	37,650	34,175	37,201
1988	45,250	42,400	39,400	35,445	38,886
1989	47,050	44,150	41,150	36,758	40,641
1990	48,900	45,850	42,950	38,104	42,413

a/Four forecasts were developed and submitted to TVA management. An official forecast has not been approved, but the Office of Power has recommended that the low forecast be adopted.

TVA's forecasts of the generating capacity needed during the 1980s have also decreased, as the following table shows. However, the forecasts continue to support the need for a total generating capacity in excess of the 44,440 megawatts estimated to be available when the Hartsville, Phipps bend, and Yellow Creek plants are completed. To provide the additional capacity which the forecasts call for, the Authority is considering two additional 1,200 megawatt units during the 1980s. However, TVA has not yet decided whether, when, or where to construct the units or what kind of units to construct.

Generating Capacity Requirements (megawatts)
(note a)

<u>Year</u>	<u>1974 forecast</u>	<u>1977 forecast</u>	<u>1978 forecasts (note b)</u>	
			<u>Low</u>	<u>High</u>
1980	33,936	30,473	27,820	28,416
1981	35,994	32,806	30,995	31,989
1982	38,241	34,614	33,509	34,992
1983	40,422	36,544	34,496	36,329
1984	43,064	39,168	36,702	39,040
1985	46,269	42,562	39,456	42,276
1986	48,498	44,846	41,062	44,355
1987	50,620	46,930	42,534	46,281
1988	52,778	49,177	44,202	48,479
1989	54,888	51,384	45,856	50,652
1990	57,098	53,401	47,328	52,674

a/Some of the forecasted demand (see p. 22) will be met with purchases from other utility companies.

b/Four forecasts were developed and submitted to TVA management. An official forecast has not been approved, but the Office of Power has recommended that the low forecast be adopted.

The above figures include TVA's estimates of the reserve capacity needed to insure sufficient supplies of electricity. Requirements for reserve generating capacity are determined by a number of factors, such as scheduled and unscheduled shutdowns of generating facilities and the types, sizes, and reliability of facilities. The recommended 1978 forecast includes requirements for reserve capabilities ranging from 28 to 30 percent, or from 6,354 megawatts during the winter

of 1980, to 10,324 megawatts during the winter of 1990. The Federal Power Commission suggests reserve capacities of 15 to 25 percent. However, the Authority believes that a reserve capacity lower than 24 or 25 percent would be inadequate for its power system, and several private utility companies even estimate needs for reserve capacities in excess of 30 percent. TVA officials said that they are contacting consultants to review and appraise the Authority's reserve planning methodology.

In our prior report on the Bellefonte Nuclear Plant, we discussed the changed trend of demand projections made by TVA. TVA officials stated that they did not plan to adjust their capacity requirements for the change in demand, because they believed a variation in 1 year's demand forecast could be considered to be an aberration.

The demand trend established in 1975 has continued. For example, the 1974 forecast of 39,800 megawatts demand in 1985 was reduced by 2,650 megawatts in the 1975 forecast by an additional 2850 megawatts through the 1977 forecast and by an additional 146 megawatts to 2,423 megawatts in the 1978 forecast. Decreases in overall demand forecasts have resulted primarily from conservation and technological advances, such as cogeneration and appliance efficiency.

If conservation programs continue to be successful and subsequent decreases continue to occur in the demand growth, then continual close scrutiny of reserve requirements will be needed to ensure overbuilding of capacity does not occur. A recent report we issued (EMD-79-91, see p. 3) demonstrates how growth projections can change, based on implementing programs such as conservation, which can also impact on needed reserve capacity. In our study, we made alternative growth projections which included an assumption that required dependable capacity be about 22-percent greater than expected peak demand. These projections indicated that there could be excess capability ranging from 6,700 to 24,800 megawatts in the year 2000. We also pointed out in this report that TVA, at that time, expected their capacity to decline from 29 percent in 1975 to 24 percent in 1985. These variations in reserve capacity needs between TVA estimates also demonstrate the need to carefully reassess such forecasts on a periodic basis.

CONCLUSIONS

TVA forecasts demand for electricity and the generating capacity needed to satisfy the demand. The demand forecasts are increased by a factor for reserve capacity to insure availability of electricity for peak demands and when generating facilities experience scheduled or unscheduled shutdowns. The Authority's 1978 forecast provides for a reserve capacity of from 6,354 to 10,324 megawatts. This is approximately equal to the expected generating capability of about one-third to one-half of the seven nuclear powerplants expected to be online by 1990.

A new trend of electrical demand growth has been established. If this trend continues, TVA will be continually lowering its demand projections for the 1985-90 time frame. Unless capacity requirements are similarly reduced, excessive and expensive reserve capacity will be the result. TVA's 1978 forecast provides for a reserve capacity of from 6,354 to 10,324 megawatts, or about 30 percent of capacity.

RECOMMENDATION

In view of the large amount of the reserve capacity and the trend of the demand forecasts, we are recommending that the Board of Directors reassess the reserve requirements.

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