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PROJECT MEMORANDUM "AN UPDATE OF THE COSTS AND BENEFITS OF RAILROAD ELECTRIFICATION"

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16. Abstract

This report contains material for use by the Federal Railroad Administration in reassessment of railroad electrification. The costs and benefits of electrification compared to continued diesel operation are established by calculating the rate of return on the differential cash flow. The rate of returns for three national networks of varying sizes are found to be marginally increased relative to calculations made in 1977. The energy impacts of electrification of the networks is discussed along with relevant environmental experience of the Northeast Corridor Improvement Project. The Conrail electrification study is summarized and the electrification demonstration project of the Tennessee Valley Authority is described.

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EXECUTIVE SUMMARY

INTRODUCTION

The preliminary report, "A Prospectus for Change in the Freight Railroad Industry," was published in October 1978 by the Secretary of Transportation in response to requirements of the Railroad Revitilization and Regulatory Reform Act of 1976 (4R Act). Appendix C of that report, entitled "Electrification Investments," addressed the costs, benefits, and energy and environmental impacts of electrification, as directed by Section 901 of the 4R Act. .

This report updates cost, petroleum consumption and other related data from Appendix C. The status of Conrail feasibility studies and Tennessee Valley Authority (TVA) planned demonstrations are also reported. This material is of concern to the Federal Railroad Administration (FRA) in its reassessment of railroad electrification.

COST TO ELECTRIFY

Three prospective rail networks were identified in Appendix C, in order of decreasing traffic density:

- A 10,000-mile network - 40 million gross tons/year, or greater
- A 26,000-mile network - the above network, plus about 43% of the remaining "A" mainlines*
- A 40,000-mile network - the above network, plus the balance of the "A" mainlines

*An "A" mainline has an annual traffic density of 20 million gross ton-mi/mi.

Appendix C also identified three site-specific rail scenarios contained in the above networks:

- Mixed freight over difficult terrain (352 route-miles)
- High-speed freight over moderate terrain (965 route-miles)
- Unit coal trains over unspecified terrain (365 route-miles)

Unit capital and operating costs for electrification of these six scenarios are updated to 1980 in this report. They are based primarily upon estimates developed for the recent Conrail electrification feasibility study. The cost data of the Conrail study was provided to the FRA as part of a Letter of Understanding between the FRA and Conrail regarding review of the study results. Those unit costs that appeared in Appendix C were obtained from the FRA data base used for the study report: "An Evaluation of the Costs and Benefits of Railroad Electrification." These unit costs, which were expressed in 1977 dollars, were used to develop the original cost estimates for the three networks.

The original and updated unit cost estimates are presented for comparison in Table E1. This table indicates significant cost increases over the last three years. While no attempt has been made in this report to assess the causes for the cost increases, it is worth noting that the cost of electric energy has shown the least escalation over this period.

Table E1

Unit Costs of Railroad Electrification

Category	Year of Estimate	
	1977	1980
Wayside Equipment:		
Single Track ($K/ route mi)	228	473
Double Track ($K/ route mi)	381	780
Locomotives:		
Diesel-electric ($K/ loco)	500	791
Electric ($K/ loco)	1000	1540
Operating Costs:		
Diesel Energy ($/ gal)	0.42	0.85
Electric Energy ($/ kWh)	0.027	0.042
Diesel-locomotive Maint. ($/ unit mi)	0.68	1.33
Electric loco. Maint. ($/ unit mi)	0.29	0.65
Catenary Maint. ($K/ route mi)	2.0	4.4

Source: Table 1 of text.

ELECTRIFICATION ECONOMICS

The comparison of electric and diesel operations is measured quantitatively by the rate of return (ROR) on the differential cash flow of the two alternatives over a specified study period. The differential cash flow includes: net investment at the beginning of the study period and net operating cost savings during the study period. Net investment is equal to the capital cost to electrify, less the credit for the diesel locomotives released for sale or absorption into other lines of the railroad. Net operating cost savings include the differentials between electric energy and diesel fuel, and between electric and diesel locomotive maintenance. Catenary maintenance is an additional operating cost associated with electrification and must be included in the differential analysis.

The net investment and net annual operating cost savings with electrified operation for the three network scenarios from Appendix C are reported in Table E3 (1977), where they are compared to the updated estimates (1980). For each of these networks, the net investment has approximately doubled, which is commensurate with the increase of wayside unit costs of Table E1. The net operating cost savings has more than doubled, which is also commensurate with the increases in operating costs of Table E1 and can be attributed primarily to the relatively small increase in cost of electricity as compared to cost of diesel fuel over this period. While locomotives represent a significant investment cost, on a net basis electric locomotive investment is largely offset by savings in diesel locomotive investment, thereby minimizing the effect of capital cost changes in motive power.

Table E3

Net Investments and Net Annual Savings for Three Network Electrification Scenarios for 1977 and 1980

(million dollars)

	10,000-mile Network		26,000-mile Network		40,000-mile Network	
Year	Net Investment	Net Savings/ year	Net Investment	Net Savings/ year	Net Investment	Net Savings/ year
1977	3,420	365	7,710	673	11,200	934
1980	6,760	822	15,700	1,510	22,800	2,080

Source: Table 2 of text.

The net investment and net annual operating cost savings for the three site-specific scenarios are given in Table E4. For these three scenarios, the updated net investments and the updated net annual savings have both more than doubled, with the increase in annual savings being slightly less than the increase in net investment in each case.

Table E4

Net Investments and Net Annual Savings for Three Site Specific Electrification Scenarios

(million dollars)

Year	Mixed Freight Over Difficult Terrain		High Speed Freight Over Moderate Terrain		Unit Coal Train	
	Net Investment	Net Savings/ year	Net Investment	Net Savings/ year	Net Investment	Net Savings/ year
1974	—	—	304	33.3	—	—
1975	145	17.4	—	—	56.3	7.20
1980	371	39.9	783	79.8	154	19.4

Source: Tables 3, 4 and 5 of text.

The ROR was calculated for each of the three network scenarios and is given in Table E5. Two basic assumptions used to determine the ROR found in Appendix C, i.e., 2% per year traffic growth and no general inflation, remain unchanged in the 1980 update. However, the originally assumed escalation of the price of diesel fuel relative to electric energy by 2% per year has been changed to 3% per year in the 1980 update to reflect the most recent projections. The estimated 1980 RORs increase marginally from the 1977 estimates because, as shown in Table E3, the net savings are increasing faster than the net investment cost.

The RORs for each of the three site-specific scenarios are also given in Table E5. The basic assumptions regarding traffic growth, inflation, and the escalation of diesel fuel cost relative to electric energy cost are different from those used for the three network scenarios. The updated RORs in Table E5 are either unchanged or marginally lower than the previous estimates. This is a result of capital cost escalations exceeding the escalations of the operating cost savings, as shown in Table E4.

Table E5

Rate of Return for Three Network and Three Site Specific Electrification Scenarios for 1974, 1975, 1977 and 1980

(percent)

Year	10,000-mile Network	26,000-mile Network	40,000-mile Network	Mixed Freight, Difficult Terrain	High Speed Freight, Moderate Terrain	Unit Coal Train
1974	—	—	—	—	18	—
1975	—	—	—	20	—	20
1977	15	12	11	—	—	—
1980	17	14	13	18	17	20

Source: Tables 6 and 7 of text.

ENERGY IMPACT

The annual oil savings projected by year 1990 from electrification of each of the three rail networks are:

- 10,000-mile network - 31 million barrels
- 26,000-mile network - 56 million barrels
- 40,000-mile network - 77 million barrels

These estimates remain unchanged from Appendix C. The recently proposed Fuel Use Act would require that by 1990 electric utilities not use liquid petroleum for the generation of electricity. Therefore, the above diesel oil savings are also the net oil savings resulting from electrification after 1990. Net savings prior to 1990 must consider the difference between the railroad diesel fuel saved and the electric utility oil burned to support electrification. The current mix of electric utility fuel is only 13% oil, with the balance obtained from sources, such as coal, nuclear, gas and hydro.

The annual oil savings resulting from electrification represents only 1/2 to 1% of the present liquid petroleum consumption of the country. However, railroad electrification is a mature, demonstrated technology, and is the only mode for intercity transport of goods and people that can be shifted from liquid petroleum based fuel without the need for additional technology development. Therefore, electrification could significantly contribute to the President's conservation goals.

CONRAIL ACTIVITY

Conrail has just completed a major electrification feasibility study in response to the requirements of Section 606(i) of the 4R Act. The 4R Act provides up to $200 million in Federal loan guarantees to extend or rehabilitate its electrification facilities if the Secretary of Transportation determines that operating and financial benefits will result. The Conrail study has shown that electrification of the sectors east and west of Harrisburg is both technically and economically feasible. For the sector west of Harrisburg (to Pittsburgh), the study has shown that new electrification at 25 kV, with a direct 60 Hz electric utility power supply connection is the lowest cost alternative. For the sector east of Harrisburg, the study has shown that retaining the existing 11 kV, 25 Hz, electrification with a dedicated power supply, and electrifying new sections at 25 kV, with a direct 60 Hz electric utility power supply connection is the lowest cost alternative.

Electrification of the entire study route requires nearly $1.2 billion. Cumulative operating savings for 29 years of over $9 billion yield a return on investment of 18.1%. The consumption of oil would be reduced by 1.7 million barrels per year.

Conrail has stated that the major obstacle to implementation is the large initial capital investment, which is beyond its means. If Federal assistance was justified based upon public benefits, Conrail has indicated that it would require a financing arrangement that reduces the initial capital requirement. One possible arrangement has been suggested to the Secretary of Transportation by Conrail, in which principal and interest would be deferred until the operating savings are sufficient to service the debt.

Conrail has indicated an eagerness to assist the Federal government in evaluating whether the project should be initiated based upon public interest. Both Conrail and the FRA are currently reviewing the study under the existing Letter of Understanding.

TVA ACTIVITY

The TVA, a Government agency responsible for the natural resources development of its region, has identified railroad electrification as one of its candidates for a national energy conservation demonstration program.

The TVA promotion of railroad electrification was initiated with a study by Battelle and is proceeding to the second step with the formulation of a three-phase program to build the TVA Electrification Demonstration Project. Battelle has identified two routes between Cincinnati and Atlanta, using the tracks of the Southern and the L&N railroads, as potential electrification candidates.

The TVA plans to establish a project management organization to be responsible for the project financing, the Railroad Electrification Management Corp. (REMC). REMC will be either a public or a private corporation which will build, own and maintain for the railroads the wayside catenary and the substations. Capital funds for REMC could be obtained from either the private financial market or the Federal Government. The REMC would offer the tax advantages, incentives and financial security to assure success of the project. It would be responsible for managing the technical and economic studies (Phase I), the system design (Phase II), and the construction (Phase III), as well as the overall project financing. The electric utilities would be responsible for the transmission facilities and the delivery of the electric energy to the substations. The railroads would be responsible for the purchase of the electric locomotives, track maintenance, purchase of the electric energy, and overall operational control. The TVA would act as a catalyst to assure cooperation among the railroads, the electric utilities, and REMC.

Approval of the Demonstration Project by the TVA Board is anticipated in May, 1980.

SUMMARY AND CONCLUSIONS

The major conclusions of the update of Appendix C are summarized as follows:

- The capital investments required to electrify the rail network scenarios of 10,000, 26,000 and 40,000 miles are \$9 billion, \$21 billion and \$30 billion, respectively.
- The escalation of diesel fuel cost in future years relative to electric energy cost has been revised

upward from 2% per year in the 1977 projection to 3% per year in the 1980 projection; the cost of electric energy in future years remains unchanged from the 1977 projection.

- For the base case scenarios analyzed, the ROR has increased marginally from 1977 to 1980, despite significant and nonuniform increases in the cost components. When escalation of the cost of diesel fuel relative to electricity is applied, an additional slight increase in the base case ROR results.

- An abrupt increase of 100% in the differential cost of energy results in a substantial increase in the ROR. It should be recognized, however, that if such a condition were to occur, the cost-push inflationary effect would, in time, impact all other electrification cost factors and would moderate the change in ROR.

- The estimated annual diesel oil savings for rail networks of 10,000, 26,000 and 40,000 miles is 31, 56 and 77 million barrels, respectively.

- Conrail has submitted to the Secretary of Transportation the results of its feasibility study; the findings are that electrification east and west of Harrisburg is technically and economically feasible. Conrail has offered to assist the Secretary in assessing whether there are sufficient public benefits to justify some form of Federal financial assistance that would relieve Conrail of the initial capital requirements.

- The TVA has indicated its intent to proceed with an electrification demonstration project which will include the formation of a Railroad Electrification Management Corporation to handle financing as well as design and construction.

Any reassessment of the role of the FRA in railroad electrification best can be justified on the basis of liquid petroleum conservation. Because there is considerable, perceived uncertainty regarding technical and cost aspects of electrification, it would appear that Government support of a demonstration project (or projects) is warranted. While the demonstration project may also provide stimulus to other railroads to electrify, it is prudent that a more defined policy be developed by the FRA to provide incentives to electrification which are consistent with the expected social benefits.

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1.0 INTRODUCTION

1.1 Background

The preliminary report, "A Prospectus for Change in the Freight Railroad Industry", was published in October 1978 by the Secretary of Transportation [1] * in response to requirements of the Railroad Revitalization and Regulatory Reform Act of 1976 (4R Act). Appendix C of that report, entitled "Electrification Investments", addressed the costs, benefits, and energy and environmental impacts of electrification as directed by Section 901 of the 4R Act.

The findings of that report were that national benefits, particularly reduction in petroleum consumption, would not be sufficiently large to warrant Government sponsorship of a major program of railroad electrification. However, certain route segments would appear to benefit significantly from electrification and a financial assistance program was proposed to offer loans in such cases. The Federal Railroad Administration (FRA) proposed to support further research and development and recommended a demonstration project to reduce uncertainty.

1.2 Review and Summary of the FRA Data Base

In preparation of Appendix C of the Prospectus, the FRA developed a substantial data base on railroad electrification. Figure 1 lists the references and source documents cited in Appendix C. Note the publication date for all citations is either 1976 or 1977.

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*Numbers in brackets indicate references at end of report.

FIGURE 1. REFERENCES AND SOURCE DOCUMENTS CITED IN APPENDIX C OF THE PROSPECTUS REPORT

TITLE	PERFORMING ORGANIZATION	REPORT DATE
• AN EVALUATION OF THE COST AND BENEFITS OF RAILROAD ELECTRIFICATION	FEDERAL RAILROAD ADMINISTRATION	1977
• A REPORT ON U.S. RAIL ELECTRIFICATION	UNIFIED INDUSTRIES	1977
• ENGINEERING COST DATA ANALYSIS FOR RAILROAD ELECTRIFICATION	A.D. LITTLE	1976
• ENERGY COST FOR RAILROAD ELECTRIFICATION	A.D. LITTLE	1977
• NATIONAL ENERGY OUTLOOK	FEDERAL ENERGY ADMINISTRATION	1976
• NORTHEAST CORRIDOR PROJECT INITIAL ASSESSMENT	DEPARTMENT OF TRANSPORTATION	1976

The draft report, "An Evaluation of the Costs and Benefits of Railroad Electrification", [2] prepared by the FRA was the primary reference. It presents a comprehensive summary of the economic, technical, and social factors of railroad electrification in the United States in 1977. The report includes capital and operating costs for both the fixed electrification plant and the locomotives. A 26,000-mile base railroad network which carries over 50% of the annual freight traffic is formulated as an electrification model to compare with sustained diesel operation. In addition to the costs to electrify the base network, the effects on the national diesel and electric energy consumption, on the sources of fuel for the electric power industry to supply the electrification energy, and on the environment are also described.

Reference 2 concluded that there are three major potential benefits of railroad electrification: (1) improved cost performance; (2) improved operational efficiency; (3) flexibility in source of fuel. The value of the first two benefits depends on how well a railroad performs without electrification. That is, for a railroad to benefit from electrification, it must be in a position to take advantage of the cost and operational advantages of all-electric traction. Rates of return (ROR) on the net electrification investment were calculated to be 15 to 20% for promising candidate routes. With regard to flexibility in source of fuel, railroads would use only about 2% of U. S. petroleum consumed annually. The advantage of electrification would occur if oil became relatively unavailable or high priced, compared to the equivalent electric energy.

1.3 Need for Electrification Factors Update

At least five factors prompt the necessity to update the costs and benefits of electrification as compared to diesel operation.

(1) Inflation in labor and equipment costs, approaching 15% per year.

(2) Severe inflation in the cost of energy, particularly the cost of diesel oil and, to some extent, electric energy.

(3) The recent North American experience with electrification projects and studies, which update construction, capital equipment, and operating cost data.

(4) Considerable spare generation and transmission capacity available to use for electrification as a result of the relatively slow electric load growth of the electric utility industry since 1974.

(5) The shift in fuel mix of the electric utilities which can impact stated national policy to limit the imports of oil by promoting conservation and the use of alternate fuels, such as coal.

Since 1976, considerable planning, design and some construction activity has occurred in the North American railroad electrification scene. The activity includes the following (The dates in parentheses indicate date of completion of work or study.):

- Study prepared by Gibbs & Hill entitled, "Conrail Feasibility Electrification Study," for the Conrail system between Newark, NJ and Pittsburgh, PA. The study treats the sectors east and west of Harrisburg independently. Results of the study are now under evaluation by Conrail and the U.S. Department of Transportation (1980).
- Start of Phase I of the Tennessee Valley Authority (TVA) Electrification Demonstration Project for electrification of the Cincinnati, Ohio to Atlanta, GA, routes of the Southern Railroad and the L&N Railroad (1980).
- Design of the electrification of the New Haven, CT to Boston, MA, railroad sector of the Northeast Corridor Improvement Project (1980).
- Construction of the 25 kV and 50 kV catenary for the railroad test track at the U.S. Department of Transportation Test Center, Pueblo, CO (1979).
- "Canadian Railway Electrification Study," prepared by the Canadian Institute of Guided Ground Transport. The study concludes that electrification at the rate of 500 to 1,000 miles per year should start immediately to optimize the ROR (1976).

- Department of Energy study conducted by SRI International, "Railroad Electrification in America's Future: An Assessment of Prospects and Impacts" (1980).

1.4 Objective of This Report

The objective of this report is to provide relevant information for FRA's reassessment of its position on railroad electrification. The factors of Section 1.3, above, will be addressed, using the sources cited.

Section 2 discusses the cost, energy and environmental effects of railroad electrification. The cost factors and economics of electrification, as well as the impacts on petroleum consumption, electric power facilities, and the environment, are all reviewed in this section.

Section 3 discusses the status of Conrail electrification extension planning activities. Section 4 discusses the status of project planning for a TVA electrification demonstration.

Computation of the rate of return on the electrification investment was made with a computer based engineering economy model at TSC. The model has the capability to escalate individual cash flow elements at specified rates to account for relative growth of costs such as diesel fuel relative to electric energy. The model has been constructed to facilitate the study of the sensitivity of the ROR to cost variations.

2.0 COST, ENERGY AND ENVIRONMENTAL EFFECTS OF RAILROAD ELECTRIFICATION

Six electrification scenarios were defined in Appendix C of the Prospectus. Three rail network scenarios with 10,000, 26,000 and 40,000 route-miles were developed by the FRA for evaluation of the impacts of electrification on a national scale. [2][3] Average unit costs stated in 1977 dollars were used to develop aggregate investment cost and operating savings for each scenario.

Three site-specific scenarios were also included in Appendix C:

- Mixed Freight, 352 route-miles, in 1975 dollars
- High-Speed Freight, 965 route-miles, in 1974 dollars
- Unit Coal Train, 365 route-miles, in 1975 dollars.

In this section, data and information presented in Appendix C are updated using publications which reflect more recent studies and experience with railroad electrification. These include the Conrail Electrification Feasibility Study [5], the Edison Electric Institute 1979 report [6], and the experience with environmental impacts on the Northeast Corridor Improvement Project [9].

2.1 Electrification Cost Factors

Electrification unit costs, net investments and net savings for the same six railroad electrification scenarios are given in Tables 1 through 5. The earlier forecasts in each table denoted "A," are taken from Appendix C, Tables C-1 through C-5 [1]. The 1980 figures, denoted "B," are based on the unit costs given

TABLE I

ELECTRIFICATION COST FACTORS

Category	A* (1977 Dollars) Costs (thousand $/ route-mi)		B (1980 dollars) Costs (thousand $/ route-mi)	
	Single-Track		Single-Track	
Capital Costs:				
Catenary	103.5		175.	
Substations & Breaker Stations	34.0		87.0	
Signal & Communications Mods.	52.5		142.	
Civil Reconstruction	27.5		53.7	
Total	217.5		458.	
	Double-Track		Double-Track	
Capital Costs:				
Catenary	190.5		318	
Substations & Breaker Stations	62.0		158[1]	
Signal & Communications Mods.	77.5		210.[1]	
Civil Reconstruction	41.25		78.9	
Total	371.25		765.	
Utility Connect Costs	10.		15.	
Operating Costs:				
Diesel Energy (¢/gal)	42.0		85.0[3]	
Electric Energy (¢/kWh)	2.7		4.23	
Diesel Loco. Maint. (¢/unit mi)	68.0		133.0[2]	
Electric Loco. Maint. (¢/unit mi)	29.0		65.0[2]	
Catenary Maint. 2-track ($/route-mi/y)	2		4.40	
	Cost (thous. $)	$/hp	Cost (thous. $)	$/hp
Locomotive Costs:				
Diesel Electric	500	196	791.	264.
Electric	1,000	200	1,540	302.

*Taken from Table C-1, Ref. 1

1. Conrail is a very high density route. The cost of signaling and communications modifications is scaled to reflect an average traffic density by the ratio of average to high figures in Table C-1, Ref. 1.
2. Based on a national average of all Class I networks. GHI maintenance data not used due to the age of the fleet and deferred maintenance of Conrail predecessors.
3. A more recent projection of fuel costs was used - a 1979 projection by ADL (Ref. 7).

TABLE 2

NET INVESTMENTS AND NET ANNUAL SAVINGS DUE TO ELECTRIFICATION FOR THREE RAILROAD NETWORKS

Category	A* (1977 Dollars)			B (1980 Dollars)		
	10,000-mi Network	26,000-mi Network	40,000-mi Network	10,000-mi Network	26,000-mi Network	40,000-mi Network
Route-miles:						
Single Track	3,700	15,600	28,000			
Double Track	6,300	10,400	12,000			
Traffic (mgtm/y)**	502,470	945,800	1,317,570			
Investments (million $):						
Catenary:						
Single Track	440.4	1,614.6	2,898.0	646.	2,730.	4,890.
Double Track	1,220.2	1,981.2	2,286.0	2,000	3,310.	3,810.
Substations	516.4	1,175.2	1,696.0	1,320	3,000.	4,330.
Utility Connects	100.0	260.0	400.0	150.	390.	600.
Signaling and Communications	682.5	1,625.0	2,400.0	1,850.	4,400.	6,500.
Civil Reconstruction	361.6	858.0	1,265.0	696.	1,660.	2,450.
Electric Locomotives	1,800.0	3,400.0	4,744.0	2,770.	5,240.	7,310.
Diesel Locomotives	-1,700.0	-3,200.0	-4,480.5	-2,690.	-5,060.	-7,090.
Net Investments	3,420.9**	7,714.0	11,208.5	6,740.	15,700.	22,800.
Annual Cost and Credits (million $):						
Diesel Locomotive Replacement	-94.0	-178.0	-249.0	-149.	-281.	-393.
Diesel Energy	-398.8	-739.2	-1,004.0	-807.	-1,500.	-2,030.
Electric Energy	381.0	706.1	959.7	597.	1,110.	1,500.
Diesel Locomotive Maintenance	-370.0	-696.3	-975.0	-724.	-1,360.	-1,910.
Electric Locomotive Maintenance	96.6	182.4	254.5	217.	409.	570.
Catenary Maintenance	20.0	52.0	80.0	44.	114.	176.
Net Annual Savings	365.2	673.0	933.8	822.	1,510	2,090.

*Taken from Table C-2, Appendix C of DOT/FRA Report (Ref. 1)

**See Appendix 1 - Errata for Appendix C of Ref. 1.

TABLE 3

MIXED FREIGHT OVER DIFFICULT TERRAIN[a]

NET INVESTMENT AND NET ANNUAL SAVINGS DUE TO ELECTRIFICATION

A* (1975 dollars)		B(1980 dollars)	
Investment Schedule	**Thousand $**	**Investment Schedule**	**Thousand $**
Catenary:		Catenary:	
1,015 mainline miles at $86,000/track-mi	87,290	1015 mainline mi at $158,200/track-mi	161,000.
63 siding & yard miles at $65,000/track-mi	4,095	63 siding and yard miles at $139,420/track-mi	8,780.
Substations:		Substations:	
19 at $560,000 each	10,640	19 at $2,717,000 each	51,600.
Switching Stations:		Switching stations:	
19 at $94,000	1,786	19 at $182,000 each	3,460.
Signaling and communications modifications:		Signaling and communications:	
369 signaled route-mi at $62,000/rt.-mi	22,878	369 signalled route-mi at $256,500/rt.-mi	94,600.
Civil reconstruction, additional increment for catenary:		Civil reconstruction, additional increment for catenary:	
Clearance only	10,380	Clearance only 352 rt.-mi at $78,900/rt.-mi	27,800.
Electric locomotives:		Electric locomotives	
70 at $880,000 each	61,600	70 at $1,540,000 each	108,000.
Diesel locomotives transferred:		Diesel locomotives transferred:	
157 at $340,000 each	(53,380)	157 at $537,700 each	(84,400.)
Net investment	145,289	Net investment	371,000.
Annual costs and credits	**Thousand $/y**	**Annual costs and credits**	**Thousand $/y**
Diesel locomotive replacement:		Diesel locomotive replacement:	
8.7 average at $500,000 each	(4,350)	8.7 average at 790,700 each	(6,880.)
Diesel fuel:		Diesel fuel:	
47 million gal at 49¢/gal	(23,030)	47 million gallons at 85¢/gal	(40,000.)
Diesel locomotive maintenance:		Diesel locomotive maintenance	
18.18 million miles at 58¢/mi	(10,544)	18.18 million miles at 133¢/mi	(24,200.)
Electrical energy:		Electrical energy:	
531 million kWh at 3¢/kWh	15,930	531 million kWh at 4.23¢/kWh	22,500.
Electric locomotive maintenance:		Electric locomotive maintenance	
10.89 million miles at 28¢/mi	3,049	10.89 million miles at 65¢/mi	7,080.
Catenary maintenance:		Catenary maintenance	
1,078 miles at $1,400/mi	1,509	352 mi at $4,400/mi	1,550.
Net annual savings	17,436	Net annual savings	40,000.

[a]Route-miles = 260 + 92 alternate; track-miles = 1078; traffic density = 97 mgt/yr.

NOTE: Numbers in parentheses indicate negatives.

SOURCE: Arthur D. Little, Inc. for the Department of Transportation Systems Center, Engineering Cost Data Analysis for Railroad Electrification, Oct. 1976, (Ref. 4)

* Taken from Table C-3, Ref. 1

TABLE 4

HIGH-SPEED FREIGHT OVER MODERATE TERRAIN[a]

NET INVESTMENTS AND NET ANNUAL SAVINGS DUE TO ELECTRIFICATION

A* (1974 dollars)		B (1980 dollars)	
Investment schedule	Thousand $	Investment schedule	Thousand $
Catenary:		Catenary:	
2,227 miles at $83,000/track-mi	184,800	2,227 miles at $158,900/track-mi	354,000.
Substations (owned by utility)	0	Substations (owned by utility):	0
Signaling and communications modifications:		Signaling and communications modifications:	
965 route-miles at $64,900 / route-mi	62,600	965 route-miles at $209,300 / route-mi	202,000.
Civil construction	18,300	Civil construction: 965 rt.-mi at $23,450/rt.-mi	22,600.
Electric locomotives:		Electric locomotives:	
198 at $1,054,000 each	208,700	198 at $2,400,000 each	475,000.
Diesel locomotives transferred		Diesel locomotives:	
397 at $430,000 each	(170,700)	397 at $680,000 each	(270,000.)
Net investment	303,700	Net investment	783,000.
Annual costs and credits	Thousand $/y	Annual Costs and credits	Thousand $/y
Diesel unit replacement		Diesel unit replacement:	
21.6 at $500,000 each	(10,800)	21.6 at $790,700 each	(17,100.)
Diesel fuel:		Diesel fuel	
124 million gal at 48.8¢/gal	(60,500)	124 million gals/y at 85¢/gal	(105,000.)
Diesel unit maintenance:		Diesel unit maintenance	
63.4 million miles at 60¢/mi	(38,000)	at $1.33/mi	(84,300.)
Electrical energy:		Electrical energy	
156 billion kWh at 4.04¢/kWh	63,000	1.56 billion kWh at 6.33¢/kWh	98,700.
Electric unit maintenance:		Electric unit maintenance:	
36.9 million miles at 28¢/mi	10,310	at 65¢/mi	24,000.
Catenary maintenance:		Catenary maintenance	
2,227 miles at $1,200/mi[b]	2,700	965 mi at $4,400/mi	4,250.
Net annual savings	33,300	Net Annual Savings	79,500.

[a] route-mi = 750 double and 215 single track; track-mi = 2,227; traffic density = 70 mgt/y and 27 mgt/y on single-track sectors.

[b] Substation maintenance by utility.

NOTE: Numbers in parentheses indicate negatives.

SOURCE: Arthur D. Little, Inc. for the Department of Transportation, Transportation Systems Center, Engineering Cost Data Analysis for Railroad Electrification, Oct. 1976. (Ref. 4).

*Taken from Table C-4, Ref. 1.

TABLE 5

UNIT COAL TRAIN[a]

NET INVESTMENTS AND NET ANNUAL SAVINGS DUE TO ELECTRIFICATION

A* (1975 dollars)		B (1980 dollars)	
Investment Schedule	Thousand $	Investment Schedule	Thousand $
Catenary:		Catenary:	
595 miles main-line at $64,000 track-mi	38,100	595 miles main-line at $158,900/track-mi	94,500.
34 miles yard wiring at $55,000/track-mi	1,900	34 miles yard wiring at $119,175/mi	4,050.
Substations:		Substations:	
3 single track at $506,000 each	1,500	3 single track at $1,638,000 each	4,910.
6 double track at $905,000 each	5,400	6 double track at $2,425,000 each	14,600.
Switching stations:		Switching stations:	
3 single track at $72,200 each	200	3 single track at $130,000 each	390.
6 double track at $94,000 each	600	6 double track at $182,000 each	1,090.
Signal modifications (microwave now installed):		Signal modifications (microwave now installed):	
365 route-mi at $30,000/route-mi	11,000	365 mi at $98,900/mi	36,100.
Civil reconstruction:	2,300	Civil reconstruction:	3,800.
Electric locomotives: 30 at $940,000 each	28,200	Electric locomotives: 30 at $1,540,000 each	46,200.
Diesel locomotives transferred:		Diesel locomotives transferred:	
79 at $416,000 each	(32,900)	79 at $657,900 each	(52,000.)
Net Investment	56,300	Net Investment	153,640
Annual Costs and Credits	Thousand $/y	Annual Costs and Credits	Thousand $/y
Diesel unit replacement:		Diesel unit replacement	
4.6 at $500,000 each	(2,300)	4.6 at $790,700 each	(3,640.)
Diesel fuel:		Diesel fuel:	
22.3 million gal at 42.6¢/gal	(9,500)	22.3 million gallons at 85¢/gallon	(19,000.)
Diesel unit maintenance:		Diesel unit maintenance	
11.7 million miles at 60¢/mi	(7,000)	at 133¢/mi	(15,600.)
Electrical energy:		Electrical energy	
314 million kWh at 2.87¢/kWh	9,000	314 million kWh at 4.23¢/kWh	13,300.
Electric unit maintenance:		Electric unit maintenance	
5.9 million miles at 28¢/mi	1,700	at 65¢/mi	3,840.
Catenary maintenance:		Catenary maintenance:	
628 miles at $1,400/mi	900	365 miles at $4,400/route-mi	1,600.
Net annual savings	7,200	Net annual savings	19,500.

[a]Route miles = 365; traffic density = 70 mgt/y

*Taken from Table C-5, Ref. 1.

NOTE: Numbers in parentheses indicate negatives.

SOURCE: Arthur D. Little, Inc. for the Department of Transportation, Transportation Systems Center, Engineering Cost Data Analysis for Railroad Electrification, Oct. 1976, (Ref. 4).

in the sections of the draft Conrail study on Electric Traction Power Rates and Financial Analysis [5], with three exceptions, as noted in Table 1. These exceptions are: (1) signal and communications modifications; (2) locomotive maintenance; and (3) diesel fuel costs. Since the Conrail study did not provide unit costs for single-track construction, the single-track values in Section B are derived from the double-track values. The ratio of single-track costs to double-track costs for each 1980 cost item is based on the corresponding ratio shown in the earlier estimate (Appendix C of the Prospectus).

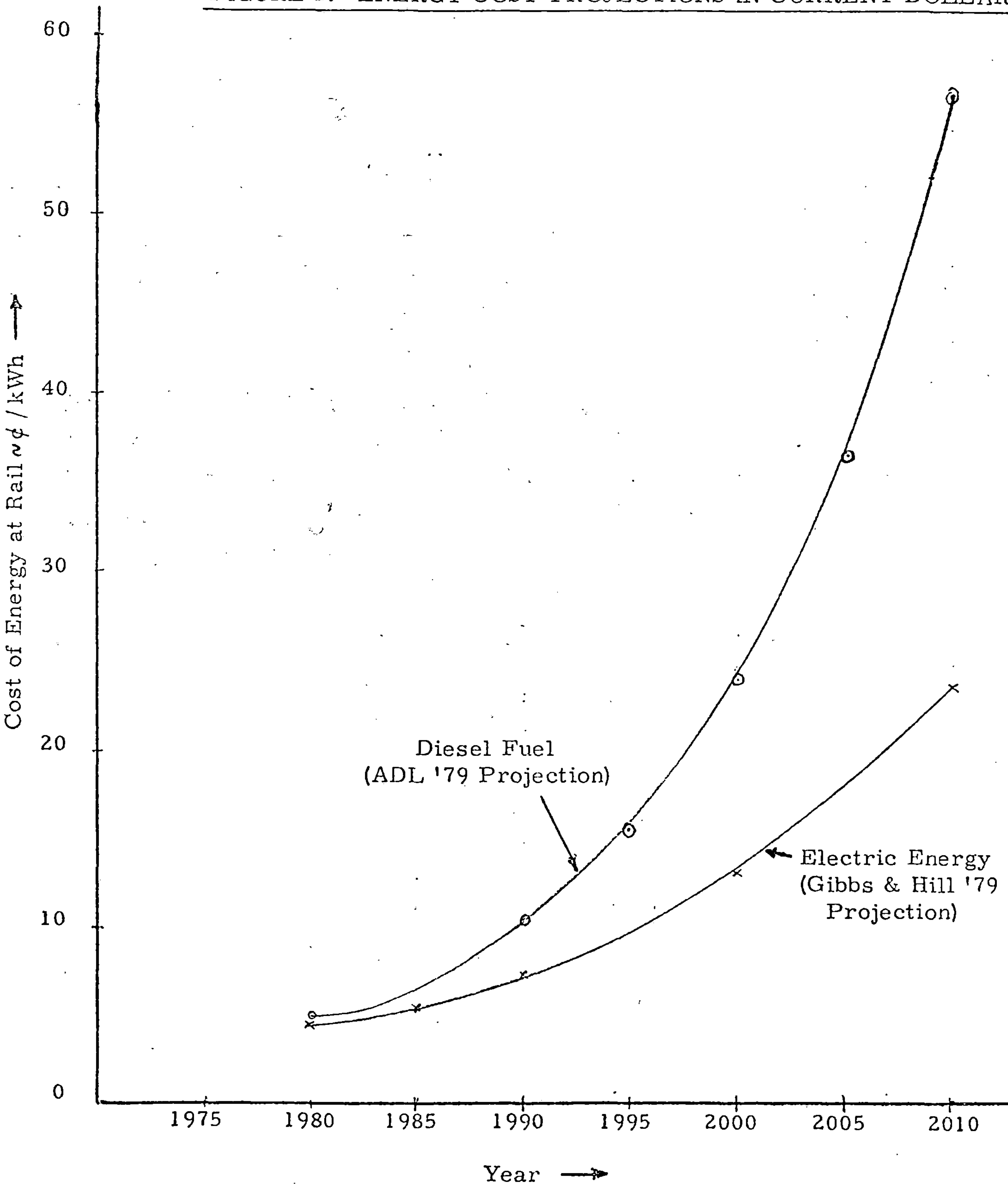
Table I, Electrification Cost Factors, shows that the various categories of capital and operating cost elements have not changed uniformly during the 1977 to 1980 period. The different escalations in costs can be ascribed to at least three factors. First, the 1977 data and the 1980 data were prepared by different organizations. Second, the 1980 data are site-specific, having been obtained largely from the Conrail system. Third, inflation has varied differently for the various components and commodities that make up each of the cost elements. It is not the intent of this report to analyze and identify the causes of the inflation and other factors contributing to the cost escalations. The 1980 figures reflect the detailed Conrail study, the initial experience on the Northeast Corridor Improvement Program (NECIP), and the extensive worldwide activity in railroad electrification, and are probably more accurate than the previous figures.

The Conrail study [5] considers four types of electric locomotives of ratings 3,700, 3,800, 4,000, 6,000 kW at rail. For the purpose of comparison with the 1977 costs given in Appendix C, the type of locomotive selected for 1980 is the type designated as "f" in the Conrail study with a rating of 3,800 kW (5,094 hp) at the rail. The cost of this locomotive for 1980 is $1,540,000 in 1980 dollars. The type of locomotive selected in Appendix C for 1977 was rated at 5,000 hp and priced at $1,000,000.

Figure C-1 of Appendix C gives the cost of traction energy for diesel and electrified operation in current dollars and was based upon projections made in 1977. Figure 2 of this report gives the same costs, but is based upon projections made in 1979. The 1979 projection of the cost of diesel fuel was prepared by A. D. Little and provided to TSC for use in review of the Conrail electrification feasibility study. [7] The cost of electric energy in Figure 2 is based upon energy and demand rates contained in the Conrail study and a load factor derived from Amtrak billings by Philadelphia Electric. [8]

The cost curve of electric energy escalates at 5.8%. The escalation rate of electric energy remains unchanged from the 1977 to 1979 projections, although the curve is shifted upward to account for actual cost of electric energy in 1980 and a revised estimate of the load factor. The cost curve of diesel fuel escalates at 9% or approximately 3% above the projected electric energy escalation; the 1977 forecast predicted that diesel fuel would escalate at 8% or approximately 2% above the projected

FIGURE 2. ENERGY COST PROJECTIONS IN CURRENT DOLLARS



electric energy escalation rate. The diesel fuel curve is also displaced upward relative to the 1977 estimate to account for actual cost of diesel fuel in 1979.

Table 2 shows the Net Investments and Net Annual Savings for the three network scenarios. The figures under Section B, 1980 dollars, were calculated from the unit costs of Table 1. Comparing A and B, the net investment for each network doubled from 1977 to 1980. The net annual savings more than doubled for all the networks over the same time interval. For the 10,000-mile network, the principal component of the net annual savings results from the replacement of diesel locomotive maintenance with electric locomotive maintenance. While these maintenance savings produced 75% of all the earlier net savings, they still are the major factor, accounting for 62% of the 1980 net savings. The net savings of electric energy over diesel energy produced only 5% of the earlier net savings. With sharply escalating fuel costs, energy savings now account for 25% of the 1980 net savings. Similar results can be shown for the 26,000-mile and 40,000-mile networks.

The net investments and net annual savings shown in Tables 3, 4 and 5 are for the three site-specific railroad scenarios. The source of the unit costs for Section A columns, is the ADL report. [4] The Section B figures for each of the tables are calculated from updated unit costs given in Table 1. These have been modified as appropriate for each scenario. Table 3 for Mixed Freight shows that the net investment and the net savings have more than doubled from 1975 to 1980. The two principal components of the net annual savings, energy and maintenance, are each about $7 million per year, out of a total of $17.4 million per year in 1975 dollars. However, in 1980 dollars, the net energy saving is $17.5 million per year and the maintenance saving is $17.1 million per year out of a total of $40 million per year. In the 5 year interval from 1975 to 1980, maintenance and energy savings have each remained at roughtly 42% of the total net savings. For the two other site-specific scenarios (Tables 4 and 5), the energy savings becomes a larger portion of the net savings in the later projections, as shown above, for the three network scenarios.

2.2 Electrification Economics

The rate of return (ROR) for electrification of each of the six scenarios described in Section 2.0, is calculated using 1974 to 1977 cost data in Appendix C of the Prospectus. Those results are reproduced here in Section A of Tables 6 and 7. For comparison, the RORs are recalculated using 1980 cost data and recorded in Section B of Tables 6 and 7.

For the three network scenarios shown in Table 6, it is assumed that rail traffic growth is 2% and there is no general inflation. The ROR for electrification is calculated both for the case of a fixed diesel fuel cost during the 30-year study period (at the 1980 level) and for the case of diesel fuel cost

TABLE 6

RATE OF RETURN FOR THREE NETWORK SCENARIOS

(percent)

Scenario	A (1977)		B (1980)	
	w/ o Fuel Differential	w/ Fuel Differential	w/ o Fuel Differential	w/ Fuel Differential
10,000 Route-mi Network	12	15**	14	17
26,000 Route-mi Network	10*	12***	11	14
40,000 Route-mi Network	9*	11***	10	13

* See Errata in Appendix I of this Project Memorandum.

** See Errata in Appendix I of this Project Memorandum.

*** See Errata in Appendix I of this Project Memorandum.

TABLE 7

RATE OF RETURN SENSITIVITIES FOR THREE SITE SPECIFIC SCENARIOS

(percent)

	A*					B (1980)					
Scenario	Base ROR	Petroleum Cost + 40%	Petroleum Cost + 100%	Electricity Cost + 40%	No Growth or Inflation	Base ROR	Petroleum Cost + 40%	Petroleum Cost + 100%	Electricity Cost + 40%	No Growth or Inflation	With Fuel Differential*
Mixed Freight	20	27	35	14	12	18	23	30	15	10	22
High Speed Freight	18	27	38	6	10	17	23	31	9	9	21*
Unit Coal Train	20	27	37	13	13	20	26	33	16	12	24

*Taken from Table C-6 of Ref. 1.

escalating during the study period relative to electric energy. The ROR results for these two cases are denoted "without fuel differential" and "with fuel differential", respectively in Table 6. The 1977 ROR calculations (column A) are made with the energy predictions of Figure C-1 of the Prospectus in which the diesel fuel differential is 2%. (See Section 2. 1.) The 1980 ROR calculations (column B) are made with the energy predictions of Figure 2 in which the diesel fuel differential is 3%. (Also see Section 2. 1).

The 1980 RORs are higher than the 1977 RORs, both with and without fuel differential escalations. These results agree with the previous observation that net annual savings had more than doubled whereas capital costs had doubled.

The RORs for the three site-specific scenarios are shown in Table 7 under the base case assumptions of 3.3% per year traffic growth and 5% per year inflation. The updated base case RORs are unchanged or are marginally lower than the previous RORs; these changes primarily result from capital cost escalation of the updated data. Variations in the cost of energy continue to have a moderate impact on the ROR. For example, Table 7 indicates that on the mixed freight route, the ROR would increase from a base case value of 18% to 30% for an immediate 100% increase in the cost of petroleum. However, sensitivity to variations in the cost of petroleum and electric energy is reduced relative to Appendix C, as the result of petroleum credits and electric energy costs becoming smaller percentages of the net annual savings of electrification (see discussion of costs in Section 2. 1). When differential fuel escalation is applied, there are marginal increases in the RORs, as in the three network scenarios (note that differential fuel escalation was not applied to the site-specific scenarios in the original Appendix C documentation). Increase of the base case ROR when differential fuel escalation is applied is less than the increase which occurs when there is an immediate 100% energy price increase, since the time value of the energy cost in the latter years of the study has less effect than the near-term costs.

The most significant conclusion in comparison of the economics of the six scenarios is that, although diesel oil cost has significantly escalated over the past few years, it alone has not driven the RORs to any higher values than those shown in Tables 6 and 7. For the site-specific cases, the cost of capital equipment has escalated more than the annual cost savings during the time period 1974 to 1980; whereas, the cost of capital equipment for the network scenarios has escalated less than the annual cost savings from 1977 to 1980. In the three network scenarios, it is primarily the escalation of electric energy at a lower rate than other commodities that has caused the increase in ROR. It can be concluded that during the 1974 to 1977 period, capital equipment was escalating at a higher rate than maintenance (labor) and energy costs; and during the 1977 to 1980 period, the annual costs were the more inflationary. This is characteristic of normal economic cycling in which the specific commodities drive the economy for some time and then begin to lag compared to other commodities. The specific impact of diesel oil cost escalation on the RORs is difficult to determine, except to note that either directly or indirectly, it has a significant influence.

2.3 Petroleum Consumption Forecast

Two forecasts of 1985 fuel consumption by the electric utilities for three railroad electrified networks are shown in Table 8. While the energy delivered to the three railroad networks under forecasts A and B of this table have not changed, the later prediction (B) projects a different 1985 fuel mix for the electric utilities than does the earlier prediction (A). The following factors were considered when generating the later forecast:

- The forecast rate of increase of coal usage by the electric utilities has only risen slightly as a result of limiting factors related to coal production, coal transportation, environmental issues, conversion of utilities to burn coal, etc.
- The requirement for the electric utilities to reduce their consumption of natural gas, combined with the sharply reduced growth rate forecast for nuclear power, is predicted to increase the 1985 oil consumption by the electric utilities beyond the earlier projections.

TABLE 8

FORECASTS OF 1985 UTILITY FUEL CONSUMPTION FOR RAILROAD ELECTRIFICATION

A* (1974 Forecast)					B** (1979 Forecast)				
Fuel Type	Fuels consumed by network size 10,000 mi	26,000 mi	40,000 mi	Railroad Load (%)	Fuel Type	Fuels consumed by network size 10,000 mi	26,000 mi	40,000 mi	Railroad Load (%)
Coal (million tons/y)	4.8	6.5	9.4	45.7	Coal (million tons/y	6.0	8.2	12.0	47.4
Gas (billion cu. ft/y)	19.5	45	58.5	11.2	Gas (billion cu. ft/y)	10.8	24.2	31.8	5.0
Oil (million barrels/y)	1.7[1]	3.3[1]	4.4[1]	5.7	Oil (million barrels/y)	4.6	8.1	10.7	14.4
All other[2]	(Nonfossil fuels)			37.4	All other[2]	(Non fossil fuels)			33.2

*Taken from Table C-7, Ref. 1

**Figures computed using Edison Electric Institute forecasts (see Ref. 6).

1. These figures are not from the DOT/FRA report. They are computed using the annual electric energy consumed by the three networks.

2. All other includes nuclear, hydro and pumped hydro generation.

The potential annual savings of petroleum fuel achievable in 1985 through railroad electrification are summarized in Table 9. The 1985 diesel fuel consumption with no electrification is based on FRA and Mitre reports published in 1977. The 1985 oil consumption by the electric utilities for electrification is based on the figures in prediction B of Table 8. The 1985 net oil savings for each rail network is the difference between the diesel fuel saved and the utility oil burned to support electrification.

The annual diesel oil savings projected for year 1990 from electrification of each of the three rail networks are reported in Appendix C of the Prospectus as:

10, 000-miles network:	31 million barrels
26, 000-miles network:	56 million barrels
40, 000-miles network:	77 million barrels

These fuel savings predictions have been reviewed and are still believed to be valid. Since the recently proposed Fuel Use Act would require that by 1990 the electric utilities not use oil for generation of electricity, the shifts in the fuel mix are not pertinent after year 1990. Therefore, the earlier predicted diesel fuel savings for each network for year 1990 in the Prospectus would also be the net oil savings, due to the mandated non-use of oil by the electric utilities.

TABLE 9

POTENTIAL 1985 PETROLEUM FUEL SAVINGS IN MILLIONS OF BARRELS PER YEAR THROUGH RAILROAD ELECTRIFICATION

		10,000 mi Network	26,000 mi Network	40,000 mi Network
1.	Diesel fuel consumption	28.0 (Ref. 3)	50.8 (Ref. 2)	69.5 (Ref. 3)
2.	Oil consumption by utilities to supply the railroad load	4.6	8.1	10.7
3.	Net oil savings*	23.4	42.7	58.8

*The difference in BTU/ gal between No. 2 diesel fuel and the heavier No. 6 oil used by the utilities is neglected here.

The savings represent only 1/2 to 1% of the present liquid petroleum consumption of the country. However, railroad electrification is a mature, demonstrated technology, and is the only mode for intercity transport of goods and people that can be shifted from liquid petroleum based fuel without the need for additional technology development. Therefore, electrification could sigificantly contribute to the President's conservation goals.

2.4 Electric Power Facilities Impact

The impact on the electric utilities is directly proportional to the miles electrified per year. For an assumed electrification program of 1,000 miles per year, the annual increment of electric powerplant capacity is about 184 MW; of transmission lines about 100 miles; and of energy about 1,000 GWh.* This annual increment is an insignificant part of the annual growth of the electric utility industry, even at the present low projected annual peak load growth rate of about 3%.

The present installed capacity in the United States is about 600,000 MW with an annual generation of 2.4 million GWh. To maintain compatibility with load growth, the annual capacity additions must be at least 18,000 MW per year. The annual addition of load is about 70,000 GWh, and the addition of transmission lines is about 10,000 miles per year. The impact on the electric power industry of the electrification of 1,000 miles per year would be about 1% of the generating capacity addition,

*GWh (gigawatt-hours) = 1,000 MWh (megawatt-hours) less than 1% of the GWh load addition, and about 1% of the transmission line additions. The impact of the electrification of 1, 000 miles per year is of the order of 1% of the additions of capacity and load to the electric power industry at the present low growth-rate of the electric power industry.

The upper limit on the impact of railroad electrification on the electric utilities can be established by assuming a complete railroad network in the range of 10, 000 miles to 40, 000 miles in place. The 10, 000-mile network requires about 1, 840 MW of generating capacity, 10, 000 GWh of energy, and about 1, 000 miles of transmission lines. This railroad network will utilize about 3% of the installed generation capacity, about 0. 45% of the energy, and about 0. 3% of the transmission lines. For the 40, 000 mile network, the utilization will increase to 0. 75% of the capacity, 1. 1% of the energy, and 0. 75% of the transmission lines.

In general, the load of the full 40, 000 mile railroad network would hardly alter the overall operations of the U. S. utility industry. On regional and local bases, the utilities will have to build facilities. The concentration of electrification would probably occur where population and electric utility facilities are already concentrated. The exception will occur in the Mountain Region where the transcontinental rail lines must traverse about 1, 000 miles east-west in an area that has limited electric power facilities. Additional powerplants could be built in the region using locally available western coal to provide the energy.

2.5 Environmental Impacts

Experience with the NECIP, as recorded by reference [9] and summarized in this section, demonstrates the successful techniques for handling the environmental impact of the catenary system, the electric power supply, and the replacement of energy sources for an electrification project. The following three laws are particularly applicable to the upgrading or construction of electrification: (1) the National Environmental Policy Act of 1969; (2) the National Historical Preservation Act of 1966; and (3) Section 4(t) of the Department of Transportation (DOT) Act of 1966, which prohibits the use of DOT funds for any project that uses publicly owned parkland or any historic resources if there is a prudent and feasible alternative. To meet these laws, FRA prepared a Programmatic Environmental Impact Statement, which had three basic functions: (1) to identify program-level decisions, such as the selection of traction power, which had regional implications on energy, air pollution, noise, cultural resources and aesthetics; (2) assess the environmental impacts of these program-wide plans; (3) identify those activities which could be fully assessed internally.

Conversion of the motive power from diesel to electric transfers the diesel exhaust emissions from the nonelectrified portion of the ocrridor to the electric generating plants. Not only is the transfer predicted to reduce the emissions to one half the total for diesel operation, but also the emissions will be further reduced by the use of nonfossil-fueled electric power plants, and by the predicted reduction of automobile, bus and air traffic. Electrification will also reduce the noise of diesel locomotives. The most significant long-term impact of new electrification is the visual intrusion of the catenary, substations and power supply lines. Preparation of site-specific environmental assessments is appropriate for four elements of the electrification program: (1) catenary placement and construction; (2) bridge modification for overhead clearance; (3) substation location and design; and (4) power supply line placement. Effective integration of the environmental considerations into the planning and design process requires, first, establishing a credible need for the instrusion and, second, a rigorous exploration and evaluation of all reasonable alternatives.

The load current drawn by electric locomotives can unintentionally affect: the power distribution and generation systems; other customers of the utility; trackside signalling systems, communications systems and grade crossing signals; and neighbors nearby to the electrified right-of-way. In the case of NECIP considerable debate arose over the potential interference to telephone service. The American Association of Railroads, the Institute of Electrical and Electronics Engineers and the American Railway Engineering Association have established the Railroad Compatibility Working Group to study electromagnetic interference problems with the long-range goal of formulating recommended design practices.

3.0 STATUS OF CONRAIL ELECTRIFICATION EXTENSION PLANNING ACTIVITIES

Electrification of the Conrail line from Newark to Harrisburg and from Harrisburg to Pittsburgh is a prime candidate for a project to establish capital and operating costs and to evaluate solutions to technical and operational problems and economics relative to diesel-electric locomotive operation. Gibbs & Hill recently completed and submitted to Conrail its feasibility report for electrification of sectors east and west of Harrisburg.[5] The sectors included in the Gibbs & Hill study are the only portions of the Conrail system currently being considered for electrification. This section describes the technical and financial results of the Gibbs & Hill study and its implications for future Conrail activities.

3.1 4R Act Provisions

The 4R Act of 1976 provides for financial support for electrification of the Corporation (Conrail) under Section 606(i) as follows:

> Under application by the Corporation, the Secretary (of Transportation) shall, --------, guarantee obligations of the Corporation for the purpose of electrifying high density mainline routes if the Secretary finds that such electrification will return operating and financial benefits to the Corporation and will facilitate compatibility with existing or renewed electrification systems. The aggregate unpaid principal amount of obligations which may be guaranteed by the Secretary under this paragraph shall not exceed $200,000,000 at any one time.

Conrail elected to perform an Electrification Feasibility Study for their lines east and west of Harrisburg, to determine if the requirements of Section 606 (i) above could be met. The study was conducted by Gibbs & Hill with Conrail funds. The results are under review by Conrail, and have been forwarded to the Secretary (of Transportation). Conrail has not yet decided to electrify, nor to apply to the Secretary for load guarantees under the 4R Act.

3.2 Study Results

The Gibbs & Hill study showed that electrification of the sectors east and west of Harrisburg is technically and economically feasible. For the sector west of Harrisburg (to Pittsburgh), the study showed that new electrification at 25 kV with a direct 60-Hz electric utility power supply required lower capital investment than electrification at 50 kV, 60 Hz or at 11 kV, 25 Hz with dedicated frequency converters. The net investment (fixed plant, electric locomotives and construction less future diesel locomotive purchases) in current dollars for the sector is $586 million and the expected return on investment is 17.7% before taxes. For the sector east of Harrisburg, the study showed that retaining the existing 11 kV, 25 Hz electrification with a dedicated power supply, and electrifying new sections at 25 kV, with a direct 60-Hz electric utility supply, required lower capital investment than modifying the existing electrification for 25 kV or 50 kV, 60-Hz operation. The new system is compatible with the existing electrification as well as with the probable renewal system that would alter voltage and frequency to 25 kV and 60 Hz. The net investment in current dollars for the sector east of Harrisburg is $200 million and the expected return on investment is 23% before taxes.

3.3 FRA Response

Should Conrail choose to proceed with part or all the electrification of the sectors described in the Gibbs & Hill study, using Federal load guarantees, the FRA is prepared to evaluate the Conrail application. The FRA has reviewed the Gibbs & Hill study in accordance with a letter of understanding between Conrail and the FRA, and is seeking clarification from Conrail of certain assumptions, calculations and results of the study.

3.4 Financing Options

The Gibbs & Hill study predicts an initial capital requirement (1980-1982) for the sector west of Harrisburg of $771 million and for the sector east of Harrisburg of $414 million for fixed electrification plant and locomotives.

In its study, Gibbs & Hill made several assumptions concerning the availability of financing. They assumed: that $200 million of Federal loan guarantees would be available under the terms of the 4R Act; that manufacturers guarantees would be available for 35% of all locomotive purchases; and that publicly held debt would be available to cover any short fall in financing rolling stock and fixed-plant acquisitions. The impact of the Federal and manufacturers' loan guarantees will reduce the overall cost of financing the project.

In a broader sense than Gibbs & Hill described in the study, Conrail may be considering combinations of the following options:

- Use retained earnings. Although such earnings are not available today, they may be available in the later years of the 1982-2010 electrification program. However, candidate investment projects other than electrification will most likely offer higher returns on investment and will therefore be given more consideration with this investment option.

- Sell preference shares to the Federal Government. The preference share is an equity instrument with certain debt characteristics that will provide Conrail with a subsidy in the form of lower payments for equity.

- Sell bonds on the public financial market. Use the Federal and manufacturers' loan guarantees to assure repayment and to reduce the interest rates.

- Use direct Federal financing. Depending upon the magnitude of the financing, request new legislation from Congress, or utilize 4R Act options other than the Federal loan guarantees, such as the loans and grants under Sections 505 and 511 of the Act. Loans could be considered with the option of deferring principal and interest payments for a specified period.

- Use third party ownership of the fixed plant. Third parties, such as electric utility companies, development corporations and regional authorities, may be able to raise money in the public financial market more easily than Conrail.

- Lease locomotives. Rely on equipment certificates, equipment leasing companies or other similar means to lease both electric and diesel-electric locomotives that will be required over the 1982-2010 period.

In the financing options listed above, third-party ownership transfers the capital burden from Conrail to a third party but imposes on Conrail an additional annual charge requirement. Third-party ownership of the fixed plant would significantly reduce the capital requirements for the sector west of Harrisburg from $771 million down to $413 million and would reduce the capital requirements for the less-fixed-plant intensive sector east of Harrisburg only from $414 million down to $340 million.

Likewise, locomotive leasing would convert a significant capital requirement to an annual charge requirement. The capital requirements for the early years would be reduced to a $358 million for the sector west of Harrisburg, and to $74 million for the sector east of Harrisburg.

The investment tax credit would be used as an incentive for a profitable enterprise to assume the investment responsibility for such options as third party ownership of the fixed plant and locomotive leasing.

3.5 Anticipated Action

Conrail has completed the first phase of its program, the Electrification Feasibility Study. If it decides to proceed further, it will carry out the preliminary design and detailed cost estimates requiring approximately one year. This will be followed by the detailed design and subsequent construction, requiring at least two additional years. Full operation could commence no earlier than 1984. Postponement of the Amtrak-Northeast Corridor electrification conversion to 25 kV south of New York may effect Conrail's decision to electrify the sector east of Harrisburg.

The FRA would respond to a Conrail request for financing under the existing 4R Act in two steps. First, the FRA would review the Gibbs & Hill Electrification Feasibility Study and make its own assessment of the technical, operational, economic and financial aspects of the proposed Conrail project. Second, on the basis of its assessment, the FRA would make recommendations for action to the Secretary on any such Conrail application requests.

4.0 STATUS OF TVA ELECTRIFICATION DEMONSTRATION PROJECT PLANNING

The Tennessee Valley Authority (TVA) objective in national energy conservation is to first demonstrate a means for energy saving within the 80,000-square-mile TVA service area, and then to project the savings when applied at the national level. TVA has three transportation demonstration projects in progress: (1) operation of battery-powered electric vehicles for the Electric Power Research Institute as part of Department of Energy Technology Evaluation Team; (2) demonstration of gasohol, as an alternative fuel, in the TVA fleet of 225 vehicles; (3) study of electrification of selected routes of L&N and Southern Railroads. This section describes the status of the electrification demonstration project.

4.1 Background

The TVA promotion of railroad electrification has proceeded in two steps. The first step was the completion of a private study by Battelle in 1978. The second step is the formulation of a three-phase program to implement the TVA Electrification Demonstration Project.

In conducting its Study, Battelle examined five candidate routes: (1) Clinchfield; (2) Southern Cincinnati to Atlanta via Chattanooga; (3) L&N, Cincinnati to Atlanta, via Knoxville; (4) L&N, Louisville to Nashville, Chattanooga to Atlanta; and (5) ICG, Chicago to Memphis. Battelle selected the two routes, Cincinnati to Atlanta, for further study; the Southern with 520 route miles, and 100 MGT/y; and the L&N with 500 route miles and 60 MGT/y. For these two routes, Battelle interviewed officers of the railroads regarding the following: (1) railroad's interest, reaction and willingness to participate and support the TVA project; (2) major problems or barriers anticipated by the railroads; (3) railroad's internal electrification studies; (4) financial considerations for electrification; and (5) system considerations required by electrification. Battelle concluded that the railroads generally are willing to participate in the project because, among other reasons, the project would provide answers to many of the uncertainties of U.S. electrified railroad operation and the economics of using 25 kV or 50 kV catenary system. Furthermore, the concept of a Railroad Electrification Management Corporation (REMC) (to be described) is acceptable to the railroads, provided that they (the railroads) maintain complete control of operation of the railroads.

Electrification on the L&N would probably begin in Decoursey, KY., the road's major classification yard 5 miles south of Cincinnati. The L&N has 14 miles of 1.1% grade as the trains climb Duff Mountain southward 25 miles south of Corbin, KY. Electrification of the Southern would probably start at its yard in Cincinnati to enable trains to climb the 6 miles 1.1% grade, Erlanger Hill, out of the Ohio River valley.

The second step of the TVA project is the formulation of the following three-phase Program Plan:

Phase I - Conduct an economic and route feasibility study for the two routes selected in the Battelle study.

- Establish the REMC.
- Develop the method for financing the program.

- The project is beginning Phase I, after a two-year internal TVA delay. Proposals have been reviewed for a contractor for Phase I, but selection has not been made. Meanwhile, TVA is studying the utility impact and will provide information to other utilities along the route. Both the Southern and L&N railroads are updating their internal electrification studies. Phase I will require about eight months' time, essentially the calendar year 1980. The results of the Phase I study may recommend that either line, or both lines be electrified.

Phase II - Prepare preliminary designs and detailed cost estimates.

- Prepare environmental impact statement.
- Phase II will require about one year, essentially the year 1981.

Phase III - Prepare detailed designs.

- Construct the electrification facilities.

- Purchase the electric locomotives.
- Phase III will require about three years, essentially the period 1982 through 1984, so that full operation can commence by early 1985.

4.2 Definition of Railroad Electrification Management Corp.

The REMC will be a public or private corporation which will build, own and maintain for the railroads the physical electrification plant, namely the catenary and the substations. The railroads would probably deal directly with the electric utilities for the purchase of energy to be used by the railroads via the REMC electrification facilities. Capital funds for REMC could be obtained from the private financial market or from the Government. In the organization and operation of REMC, TVA would act as a catalyst to assure cooperation between the railroads and the utilities. A governing group, such as a Board of Directors, will be drawn from the participating railroads, the participating electric utilities, and from a Government agency, if there be Federal interest in participating in the project because it would be a national electrification demonstration.

A flow chart of the REMC is shown in Figure 3. The REMC would offer the tax advantages, incentives and financial security to assure success of the project. It would be responsible for managing the technical and economics studies, system design, construction of the fixed plant and overall project financing. The

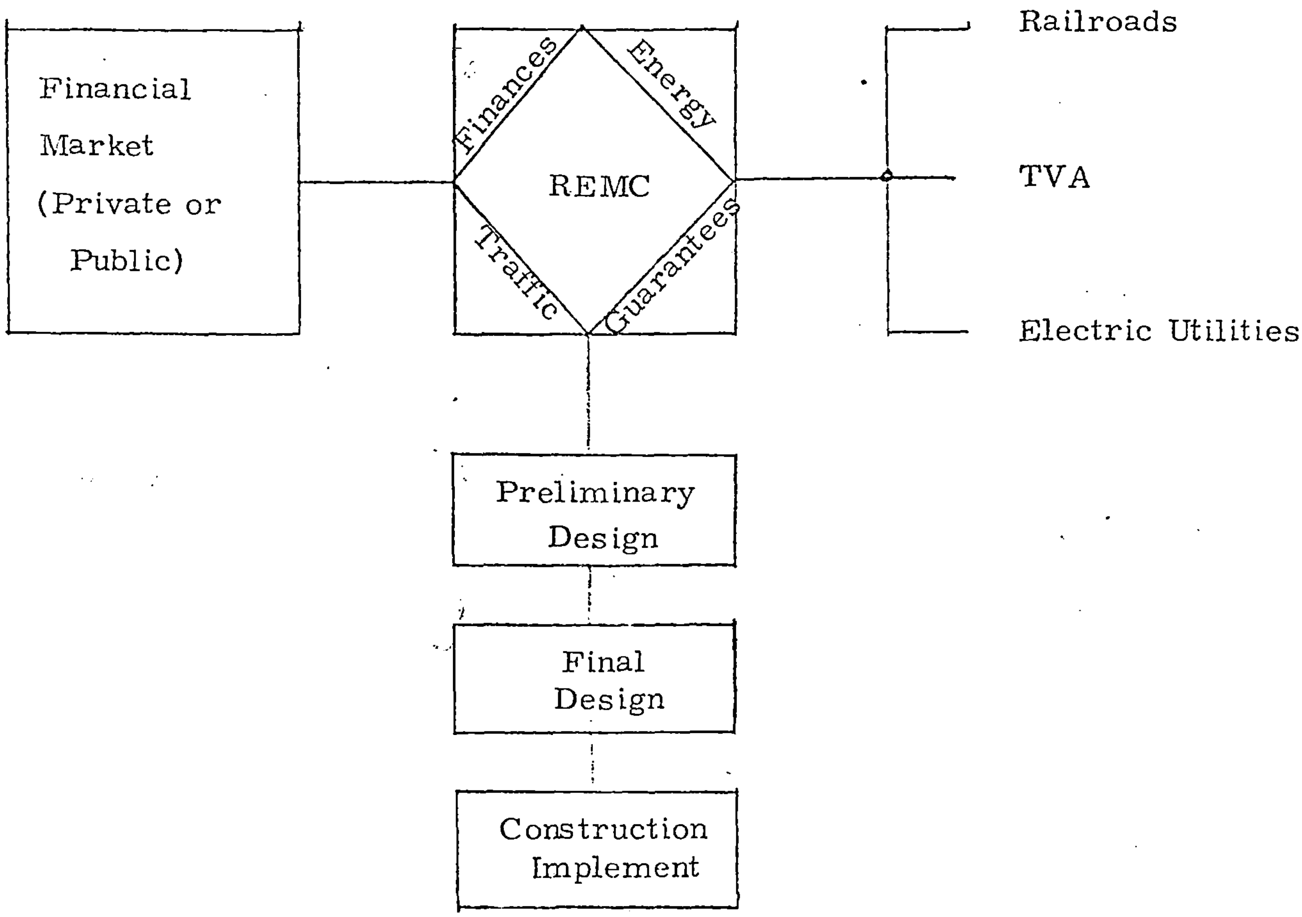


FIGURE 3. RAILROAD ELECTRIFICATION MANAGEMENT CORP.

utilities would be responsible for construction of transmission facilities to the railroad substations and the generation and supply of the energy required by the railroads. The railroads would be responsible for the purchase of electric locomotives, maintenance of the track purchase of electric energy and overall control of the operation.

4.3 FRA Support Options

The degree of FRA technical support to the TVA Electrification Demonstration Project will depend upon what agreement can be negotiated between the TVA and FRA. Using the Conrail support activity as a model, the FRA can provide expertise in the areas of project management, technology, cost and economic assessments to assist the TVA.

Potential financial support during the construction phases may be obtained through application requests under sections 505 and 511 of the 4R Act, or under new legislation.

4.4 Anticipated Action

In May 1980 TVA anticipates internal board approval of the Demonstration Project and expects to proceed with the selection of a contractor to carry out Phase I of the Program Plan. In addition, TVA may be preparing a letter to FRA requesting technical assistance, and participation in an oversight committee, for Phase I of the Program Plan.

4.5 Additional Information

An International Energy Fair (Expo '82) will be held in Knoxville, TN. Many innovative energy exhibits will be on display reflecting TVA, Oak Ridge National Laboratory, Arnold Engineering Development Center, and other agency energy efforts. Even though the railroad electrification construction would be barely underway at that time, the exposition may reflect railroad electrification efforts locally and nationally. Milestones of the national energy demonstration activities identified in Section 4.1 are planned to be displayed.

APPENDIX I

ERRATA OF APPENDIX C OF THE PROSPECTUS REPORT

The following changes apply to Appendix C of Ref. 1:

(1) Page 180, Column 1, lines 4 and 5: "increase to 18 percent to 24 percent" should read "increase to 11 percent to 15 percent."

(2) Page 180, Fig. C-1: Caption "(1977 dollars)" should read "(current dollars)."

(3) Page 181, Column 2, line 13: "24 percent" should be "15 percent."

(4) Page 181, Column 2, line 18: "18 to 20 percent" should be "11 to 12 percent."

(5) Page 183, Table C-2: Net investment in 10,000-mi network should read \$3420.9 instead of \$3401.1. Source for Table C-2 is "Federal Railroad Staff Study."

(6) Page 183, Table C-2: Item "Traffic Density (mgt/y)" should read "Traffic (mgtm/y)."

(7) Page 184, Table C-3: The footnote "960 Route-miles" should read "260 Route miles."

(8) Page 184, Table C-4: (Signal & Comm. mileage should be 965; Electric Loco. cost should be \$1.054 M; Electric energy should be 1.56 billion kWh).

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1. "A Prospectus for Change in the Freight Railroad Industry," A Preliminary Report by the Secretary of Transportation, October, 1978.

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4. "Engineering Cost Data Analysis for Railroad Electrification," Arthur D. Little (for U.S. DOT, TSC, Cambridge, MA), October, 1976.

5. "Conrail Electrification Feasibility Study," Gibbs & Hill, Draft Report, 1979.

6. "1979 Annual Electric Power Survey," a report of the Electric Power Survey Committee of the Edison Electric Institute, April, 1979.

7. A. D. Little working memorandum to DOT/TSC, "DOT Fuel Forecast Evaluation," dated 5/25/79.

8. "Review of Conrail Electrification Feasibility Study, Task XI - Electric Traction Power Rates," Alexander Kusko, Inc., Task DOT/TSC-1452-25, December, 1979.

9. "Railroad Electrification and the Environment, Northeast Corridor Project Experience," T. E. Barron, Presented to the Fifty-ninth Annual Meeting of the Transportation Research Board, Washington, D. C., January 22, 1980.

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