TECHNICAL REPORT

ENERGY USE ANALYSIS

LOS ANGELES RAIL RAPID TRANSIT PROJECT
"METRO RAIL"

Draft Environmental Impact Statement and
Environmental Impact Report

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ENERGY USE ANALYSIS

INTRODUCTION

Energy use implications of Metro Rail alternatives are discussed herein. The general approach involves compiling energy use estimates for automobile and bus use (based on VMT) for the no project condition i.e., Year 2000 base conditions, and for project conditions. When added to a comprehensive energy use analysis of the Metro Rail alternatives, energy use-benefit relationships of the project are derived. All calculations have been converted to British Thermal Units (BTUs) to allow direct comparison.

EXISTING CONDITIONS

Energy Supply

Electricity is supplied to the regional core by the City of Los Angeles Department of Water and Power (LADWP). The service area encompasses the 464-square mile City of Los Angeles which extends 43 miles in a north-south direction, and 29 miles in an east-west direction. Principal power system facilities are located throughout much of the western states and include electric generating stations, receiving and switching stations, and transmission lines. The transmission lines extend to the city from hydroelectric and steam electric generating stations and Hoover Dam on the Colorado River; Owens Gorge in the eastern Sierra Nevada; Castaic Pumped Storage Project north of Los Angeles, the Federal Columbia River Power System in the northwest; and the Navajo, Mohave, and Coronado Coal-fueled generating stations in Arizona and Nevada. Transmission and distribution occurs within the City of Los Angeles as well.

During fiscal year (FY) 1980-81, approximately 20.1 billion kilowatt hours KWh of electricity was produced or purchased to satisfy LADWP customer demand. Nearly half of this amount was produced within the Los Angeles basin by steam generating plants. One-third was produced by the Coronado, Mohave, and Navajo generating stations. Hydroelectric sources supplied approximately 13 percent, and 6 percent of the demand was purchased or provided by net interchange supplies from other companies such as Bonneville Power Administration and 17 other western utilities. Electricity consumption during FY 1980-81 was dominated by commercial customers who accounted for over one-third of total consumption (8.5 billion KWh). Residential and industrial uses each totalled approximately half of this figure, or 4.8 and 4.0 billion KWh, respectively. All users exhibited an overall reduction of energy use per customer; however, actual commercial consumption increased by 163.8 million KWh over FY 1979-80 levels.

Although 20.1 billion KWh was consumed by LADWP customers, including an allotment for energy losses within the sytem, a total of 32.9 billion KWh passed through the system. The 12.8 billion KWh difference constituted delivery to outside utilities and purposes and enterprise losses associated with use and maintenance of the system. As the system transmitted this amount of energy, it is conceivable that a future demand increases within the LADWP service area could be accommodated, within the existing system, by utilizing a larger portion of the total energy transmitted for customer service.

To maintain a continued supply of reliable and economical electricity, LADWP is participating in a number of energy development projects both in cooperation with other public agencies and singularly. Cooperative efforts include involvement with the Palos Verde Nuclear Generating Station in Arizona; the Intermountain Power Project, a coal-fueled facility under construction in Utah; and the White Pine Power Project, also a coal-fueled plant to be constructed in Nevada. Additional fueled sources under consideration include geothermal, solar and cogeneration.

By the Year 2000, LADWP anticipates their peak power supply to be 7628 MW, and their average demand for the year to be approximately 40.1 billion KWh. Nearly half of LADWP's power supply will be produced by coal (46 percent). The remaining electricity will be produced by gas/oil (17 percent), nuclear (8 percent), hydroelectric (7 percent), geothermal, solar and cogeneration (13 percent), and 9 percent will be purchased.

Natural gas is supplied to the regional core by the Southern California Gas Company (SCG). The SCG service area encompasses the majority of Southern California from Visalia and Cambria in the north to the Mexican border. Areas excluded are San Diego County and the City of Long Beach who purchase gas from SCG. Gaslines provide delivery from outside the service area and are part of the major natural gas delivery system grid. Sources of natural gas to the SCG service area are from Texas (El Paso Gas), the Transwestern Supply System, and from local production.

The regional gas-user population in 1980 was 3,725,000 customers. This was divided into 202,000 commercial and industrial customers (5 percent) and 3,523,000 residential customers (95 percent). Total retail sales in 1979 were 920,735 million cubic feet (MMcf); in 1980 777,151 MMcf; and in 1981, 801,301 MMcf. The sales volumes have not been temperature adjusted. The years 1980-81 were much warmer than normal and the reduction in demand would be signficantly influenced by changing weather (SCG, 1982). By the Year 2000, the demand on SCG system is estimated to be 951,964 MMcf; however, future demands within the system will depend upon the rate of increase in user population, conservation measures taken, and the cost and supply capabilities of the SCG system (California Gas Report, 1981).

Regional Gasoline Consumption

In the Los Angeles Regional Transportation System (LARTS), gasoline sales in 1980 were 5,087,173,356 gallons including aviation gasoline sales. Substantial fuel sales reductions are forecast for the Year 2000 by SCAG. The reduction of gasoline sales will depend on the user population and increased fuel economies for vehicles. SCAG estimates aviation gasoline sales to equal roughly one-half of one-percent of LARTS regional gasoline sales. Assuming a conservative case of one percent reduction in gasoline sales per year; by the Year 2000 gasoline sales for LARTS will be 4,140 million gallons, without aviation gas sales.

Transportation Energy Demand

The predominant elements of transporting people within the Metro Network are automobiles and buses. The major transportation energy components of these elements are: propulsion, maintenance, vehicle manufacturing and guideway construction. Energy required to support transportation in the Year 2000 has been determined by calculating the amount of energy required for each of the above components per vehicle mile traveled (VMT).

Vehicle propulsion energy is the primary user of energy in the tranportation sector. Automobile/bus propulsion energy is influenced by two primary factors: motor/vehicle design and operating conditions. In 1980, the average fuel economy for an automobile was 0.05 gallons (6,250 BTUs) per vehicle mile traveled (VMT) and 0.21 gallons (29,000 BTUs) per bus VMT. By the Year 2000, increases in overall motor fuel efficiencies are expected to increase fuel economy for automobiles by 20 percent, or 5,208 BTUs per VMT (Transportation Research Board, 1982). No major improvements are anticipated for bus fuel economy due to the operational characteristics of buses in the Metro Network. Limited potential for increased fuel ecnomy is due to the quick acceleration and frequent stops, which characterize bus operation in a dense urban area.

Maintenance of vehicles is the second largest consumer of energy in the transportation sector. Energy is primarily required for repairs, parts and lubrication, and varies with a vehicle's age, size, operational characteristics and number of its optional items. Considerable variation in the amount of energy required to maintain a vehicle is likely to occur. For comparison purposes, 1,600 BTUs per automobile VMT and 1,000 BTUs per bus VMT, will be used to represent vehicle maintenance energy (Congressional Budget Office, 1977).

Energy used in manufacturing vehicles depends primarily on the weight, materials, fabrication technology and indirect uses by the facility in which the vehicle is built. Total energy used to manufacture vehicles is substantial; however, when spread over the life of the vehicle, is usually not of major significance relative to propulsion energy. In addition, since vehicles which operate in the Metro Network also provide transportation in other areas, only a percentage of the energy used in manufacturing vehicles can be evaluated. For comparison purposes, 1,100 BTUs per automobile VMT and 1,200 BTUs per bus VMT will be used to represent vehicle manufacturing energy requirements (Congressional Budget Office, 1977).

Construction of guideways requires a substantial portion of the total energy needed to support transportation modes. The exact percentage is a matter of controversy. At the suggestion of the Transportation

Research Board of the National Academy of Sciences, SCRTD had its Metro Rail construction energy estimate checked by the Argonne National Labratory who confirmed its reasonableness.

RTD has proposed that SCAG undertake a detailed study of transit and freeway construction energy which would use actual project records of energy in place of previous theoretical estimates.

Estimated automobile/bus VMT for the region in the Year 2000 is 68,445 million miles per year (Schimpeler-Corradino, 1983) and 105 million miles per year (SCRTD, 1983) respectively. Using the above factors for energy consumption, Year 2000 energy requirements for projected VMT without project in the Metro network will equal approximately 544,539 billion BTUs. Total energy demand breaks down into 359,506 billion BTUs (66 percent of the total) for vehicle propulsion 109,617 billion BTUs (20 percent of the total) for vehicle maintenance, and 75,416 billion BTUs (14 percent of the total) for vehicle manufacturing.

IMPACT ASSESSMENT

Locally Preferred Alternative (LPA)

Operational functions of the LPA will require energy either directly or indirectly for: traction power (propulsion), station operation, maintenance, and vehicle manufacturing.

The traction power requirement is a function of the number of car miles traveled, the total number of cars, and the energy needed per car per mile. Traction power includes all energy demands for vehicle propulsion, lighting, heating and air conditioning. Eighteen traction power substations will provide electricity to the Metro Rail System. The amount of traction energy required to support this system will vary with the weight and aerodynamics of cars, station spacing, the use of regenerative braking or vertical profiling, the passenger loading factor, the average speed and electric motor power per ton of vehicle. Southern California Rapid Transit District (SCRTD) estimates that the LPA will have a peak traction power demand of 58 MW; with an average total traction energy draw of 64.2 million KWh per year. SCRTD projects the Year 2000 VMT for the Metro Rail transit vehicles to be 10,533,000 per year (SCRTD 1983). Assuming projected VMT and the average traction draw for the system, approximately 6.0951 KWh will be required per VMT. During rush hours, the system is being planned to run at 150 percent overload with a peak power demand of 92 MW. The thermal energy (in BTUs) required to provide 64,200,000 KWh per year can be obtained by multiplying by 10,000 BTUs per KWh. This accounts for transmission/line losses and thermal power plant inefficiencies (Healy, 1973). Thus, the average traction power for the LPA would require 642 billion BTUs per year, or 60,951 BTUs per VMT.

Station energy is required primarily to operate lighting, escalators/elevators, heating, ventilation and air conditioning. Proposed are 16 stations for the LPA. All stations will have energy intensive options such as escalators and elevators. SCRTD estimates the 16 subway stations to have an average electricty demand of 28,300,000 KWh per year, with a maximum demand of 1,500 kVA per station. Lighting will require 22 percent of this load and space conditioning, elevators, escalators and other auxiliary uses will require the remaining electricity demand. In addition, some natural gas is expected to be used for space and water heating. Assuming the identical thermal conversion factor as for traction power, electricity demand for the 16 subway stations will require 453 billion BTUs per year.

Maintenance energy, for a heavy rail system, is the energy required to repair and maintain vehicles and associated equipment, and to provide heat, light, traction and auxiliary power to the maintenance facility. Proposed is a maintenance facility, including a yard and shop. SCRTD estimates the total power requirements for these maintenance facilites to be 10,200,000 KWh per year. Assuming the identical thermal conversion factor as for traction power, the proposed project will require 102 billion BTUs per year for maintenance.

Energy required to manufacture the proposed 214 vehicles depends primarily on weight, materials, technology and indirect uses by the facility in which the vehicles are built.

Manufacturing energy for the type of vehicles proposed varies widely; however, for comparison purposes, 4,100 MBTUs will be used to present manufacturing energy requirements per new heavy rail transit vehicle (Congressional Budget Office, 1977). Assuming 4,100 MBTUs per vehicle, the 214 proposed vehicles (ultimately needed) will require 880 billion BTUs to manufacture. The LPA will require 130 vehicles in the Year 2000.

Construction energy will be required to build the LPA, including guideways, stations and associated facilities. Guideway construction energy is influenced by many factors, the primary factor being the type of construction method used. The project will use a combination of "cut-and-cover" techniques and tunneling, which are the most energy-intensive methods for building a heavy rail transit system (Congressional budget office, 1977). The amount of energy required for construction is difficult to estimate due to uncertainties in design details. Two methodologies most widely used to estimate construction energy are the "Process" and "input/output" methods. At present, may transit system planners are relying on Deleuw, Cather Company's use of the "process analysis" to estimate construction energy. Deleuw Cather estimate that 117 billion BTUs are required to build 1 mile of a heavy rail subway system. When considering construction of the entire system (stations, maintenance yards, etc.), the additional infrastructure can add five to six times as many BTUs per mile to guideway construciton requirements (International Business Services, Inc, 1979). Assuming total system construction energy requirements to be 585 billion BTUs per mile (believed to be the best estimate given available data), construction of the LPA will require 10,900 billion BTUs.

The LPA will require 1,197 billion BTUs per year to operate, 10,900 billion BTUs to construct and 880 billion BTUs to manufacture vehicles. Project operation and maintenance requirements of 1,197 billion BTUs per year, (119,700,000 KWh/year) would represent .003 percent of LADWP's projected Year 2000 electricity demand. Project electricity demand will not adversely impact LADWP's ability to supply electricity to its customers. In order to compare initial capital energy cost (construction and vehicle manufacturing) with operating energy, it has been assumed that the system operates for 50 years and for comparison purposes only, divide total construction and vehicle manufacturing energy by this factor. The total annual energy demand for the LPA (shown in Table 1) would be 1,433 billion BTUs per year in the Year 2000. The annual amount of total construction and vehicle manufacturing energy would remain constant throughout the 50-year comparison provided. Operating energy would be lower prior to the year 2000, during system startup and higher later, as more vehicle miles of service are run.

Table 1

TOTAL ANNUAL ENERGY DEMAND FOR
THE METRO RAIL PROJECT LPA
(billion BTUs)

	Energy	Percent of Total
Construction	218	15
Vehicle Manufacturing	18	1
Traction	642	45
Stations	453	32
Maintenance	102	7
Total Energy Required	1,433	100

SCRTD estimates that operation of the LPA and associated bus systems will decrease projected Year 2000 automobile VMT in the region by approximately 554 million auto vehicle miles per year (approximately 0.8 percent) and 3 million bus VMT (approximately 2.9 percent). Considering Year 2000 projected automobile energy requirements for vehicle propulsion, maintenance and manufacturing, a decrease in automobile VMT by 554 million miles per year would save a total of 4,380 billion BTUs. A decrease in bus VMT by 3 million per year would save 89 billion BTUs. Total energy savings from reduced VMT would be 4,469 billion BTUs; 2,967 billion BTUs for vehicle propulsion, 889 billion BTUs for vehicle maintenance, and 613 billion BTUs for vehicle manufacturing. A reduction of 554 million automobile VMT would conserve 23 million gallons of gasoline in propulsion energy and a reduction of 3 million bus VMT would conserve 650,000 plus gallons of diesel in propulsion energy. An annual reduction in propulsion energy requirements of 23 million gallons of gasoline and 650,000 gallons of diesel would represent a .006 percent decrease in estimated Year 2000 gasoline/diesel sales for LARTS.

The LPA will require a total energy demand of 1,433 billion BTUs per year and with its associated bus system is projected to save 4,469 billion BTUs per year in reduced automobile and bus VMT, resulting in a net 3,036 billion BTUs savings. Table 2 shows that the energy demand for transportation in the Metro network would decrease by one-half of one-percent, from 544,539 billion BTUs per year without the project to 541,503 billion BTUs per year with the LPA.

The projected decrease in transportation energy use resulting from the LPA represents a minor positive impact on energy resources. In addition, there are a number of other positive effects inherent in the Project's energy use characteristics. Foremost is that Metro Rail will be operated by electricity which is produced by a variety of sources including coal, hydro, nuclear, and renewable resources. Utilization of electricity and net reductions in vehicle miles traveled constitute a lessening, albeit a small one compared to State totals, of dependence on petroleum products. At last one study concludes that additional medium term energy savings from fixed rail projects can be projected as individuals make residential choices to take advantage of rail transit (Pushkarev, 1982).

Traffic data show that the LPA will reduce to varying degrees traffic volumes on Metro Network roadways over what would occur in the Year 2000 without the Project. In a few instances, traffic decreases are substantial enough to improve volume to capacity V/C ratios. Even when traffic reductions are not enough to change the V/C ratio, the incremental reductions have the positive energy effect of reducing traffic congestion.

The Aerial Option

Assuming the LPA system's energy requirements for vehicle manufacturing, and system operation/maintenance, the Aerial Option (for the rail system only) will require 880 billion BTUs to manufacture vehicles and 1,153 billion BTUs per year to operate/maintain. Construction energy requirements will be less for the Aerial Option as opposed to the LPA due to the design change of a 2.5 mile rail segment from Universal City to the North Hollywood Station. This 2.5-mile rail segment, under the Aerial Option, will be elevated rather than built underground. Elevated rail systems require less construction energy than do subway systems; 277 billion BTUs per mile for elevated versus 585 billion BTUs per mile for subway (International Business Services, Inc. 1979). Assuming 16.1 miles of subway and 2.5 miles aerial rail, the Aerial Option will require 10,111 BTUs to construct. Total annual energy demand for the Aerial

Option would be 1,371 billion BTUs; 62 billion BTUs per year less than the LPA. Also, station energy use for the Aerial Option would be less than the LPA because two of the stations would be built above ground. Above ground stations require about one third less energy than subway stations. Energy use associated with VMT is considered equal to the LPA. Energy factors for the Aerial Option are shown in Table 2.

Minimum Operable Segment (MOS)

The MOS will be 8.8 miles long. The MOS will require 741 billion BTUs per year to operate/maintain, 5,156 billion BTUs to construct, and 303 billion BTUs to manufacture vehicles. Total annual energy demand for the MOS would be 850 billion BTUs, 583 billion BTUs per year less than the LPA.

The Minimum Operable Segment would result in a total annualized energy demand of 540,984 billion BTUs (Table 2). The resulting annual savings in gasoline and diesel would be 22.5 million gallons of gas and 850,000 gallons, respectively. Like the Locally Preferred and Aerial Option Alternatives, the Minimum Operable Segment would not have a significant impact on th ability of LADWP to supply electricity to its customers.

COMPARISON OF PROJECT ALTERNATIVES

For all project alternatives, propulsion energy - largely made up of automobile and bus energy associated with VMT -- is the largest signal consumer of energy for the system. The Locally Preferred Alternative will require a total energy demand of 1,433 billion BTUs per year. The LPA would save a net of 3,036 billion BTUs per year in reduced automobile and bus energy that would otherwise be consumed if the project were not built. Table 2 shows that the energy demand for transportation in the Los Angeles region would decrease .5 percent, from 544,539 billion BTUs per year with the No Project Alternative to 541,503 billion BTUs per year with the Locally Preferred Alternative.

MITIGATION MEASURES

SCRTD has evaluated numerous energy conservation options for the construction and operation of Metro Rail. Major adopted mitigation measures are listed below in two separate groups: propulsion energy and second, station and facilities design. A third section, following the first two, lists energy mitigation options on which decisions have not yet been made, due to their technical complexity. The feasibility of the items listed in this third section will be determined in the final engineering process.

Although energy conservation measures during construction and in support activities (stations, maintenance, administration) will help, the most significant savings are likely to occur from

Table 2

LOS ANGELES BASIN TRANSPORTATION ENERGY DEMAND, YEAR 2000
(bilions of BTUs)

Energy Demand	No[1] Project	Locally Preferred Alternative	Aerial Option	Minimum Operable Segment
Guideway Construction	---	218	200	103
Vehicle Manufacture	73,416	74,821	74,821	74,821
Vehicle Maintenance.[2]	109,617	108,830	108,830	108,834
Vehicle Propulsion[3]	359,506	357,181	357,181	356,915
Station Operation	---	453	409	311
Total	544,539[3]	541,503	541,441	540,984

reducing the traction energy required to stop and start vehicles and, secondarily, from diverting more patrons from their automobiles to transit.

PROPULSION ENERGY CONSERVATION[4]

Significant kinetic energy is created when a Metro Rail train is brought up to speed; when the train is braked to a stop, this energy is typically wasted.

SCRTD will equip Metro Rail vehicles to recapture some of the energy used to stop trains through regenerative electrical braking, a generally proven technique. Regenerative braking captures energy that would otherwise be dissipated into the subway as heat; this heat would, in turn, require additional ventilation and cooling energy.

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[1] To maintain consistency within the EIS, the No Project Alternative assumes no major additional transportation facilities will be built in the Regional Core. As the traffic analyses of the existing condition shows, however, little or no additional capacity is available on the existing street and freeway system.

[2] Does not include highway repair and reconstruction, maintenance, energy consumed by gasoline stations and so forth. Does include rail transit maintenance energy consumption.

[3] Does not incorporate reductions in fuel economy, resulting from the aggravated congestion that would occur.

The real benefits of regenerative braking depend, however, on the ability to make use of the electrical power pumped back into the traction power system. If another nearby train is just starting up, one train's braking energy can be effectively absorbed by this other train. This is often not the case, but SCRTD will provide for regenerative braking energy use or energy storage wherever feasible.

Another propulsion energy conservation measure Metro Rail will utilize is "chopper" (semiconductor) traction motor speed controls instead of conventional "cam" (mechanical) speed controls. Although much heavier and bulkier, the new "chopper" control technology is considered to offer, on balance, significant energy (and other) benefits for Metro Rail. Use of extra-high voltages (1000 volts or more) and AC current have also been investigated for their energy saving potentials, but have been found to involve too many technical uncertainties to be feasible.

A variety of other mitigation measures will improve propulsion energy efficiency. A special aluminum steel-clad "third rail" which would be a much more efficient conductor than the conventional steel rail. Initial installations of this compound rail have been promising. An automatic control system for tain speed which promotes coasting will be implemented. Rail vehicles will be designed and operated so that they are switched off whenever not in service. In addition, the traction system will be designed so that it can eventually be integrated with any adjacent future electrical transit systems such as trolley buses and light raiil systems, facilitating more efficient utilization of Metro Rail regenerative braking energy.

STATION AND FACILITIES DESIGN

Metro Rail will aggressively pursue station area joint development wherever it is economically and environmentally sound and in keeping with adopted local plans. Some of the most major opportunities for saving energy in and around stations can come from integrating station design and construction into stores, offices, and apartment complexes. These sorts of "joint development" and "mixed use" design concepts not only save building construction and operating energy, they help "pedestrianize" travel that otherwise would require vehicular energy.

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[4] Refer to Draft Report for the Development of Milestone 8: Systems and Subsystems; Alternative Analyses for Traction Power (14CAD11) Report (Kaiser Engineers, November, 1982); Alternatives Analyses of Auxiliary Power (14CAD12) Report (Kaiser Engineers, December, 1982), for greatetr detail and additional measures.

Integrated station area design can achieve energy conservation in other ways as well. Interconnected heating and cooling (or other "districting" systems), for example, might save considerable amounts of energy. Building cooling systems might also be used to capture regenerative braking energy; one new CBD building, for instance, already stores off-peak electrical ventilating energy for up to 24 hours in a 50,000 gallon ice tank. In pursuing Joint Development, Metro Rail will utilize existing elevators to satisfy handicap accessibility requirements whenever possible.

During final design, every aspect of station design will be reviewed in order to minimize lighting, heating, ventilating and air conditioning loads. Air conditioning requirements will be minimized by designing the stations to facilitate ram air exchange by utilizing the piston effect of the trains. The station interior passenger area's lighting will be designed to be turned off during off-service hours. Any station hot water use will include solar hot water pre-heating where feasible.

In the maintenance yard, cold water will be utilized for vehicle washing. The track layout will be designed to minimize non-revenue vehicle movements, and solar hot water preheating will be used for hot water and steam needs.

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