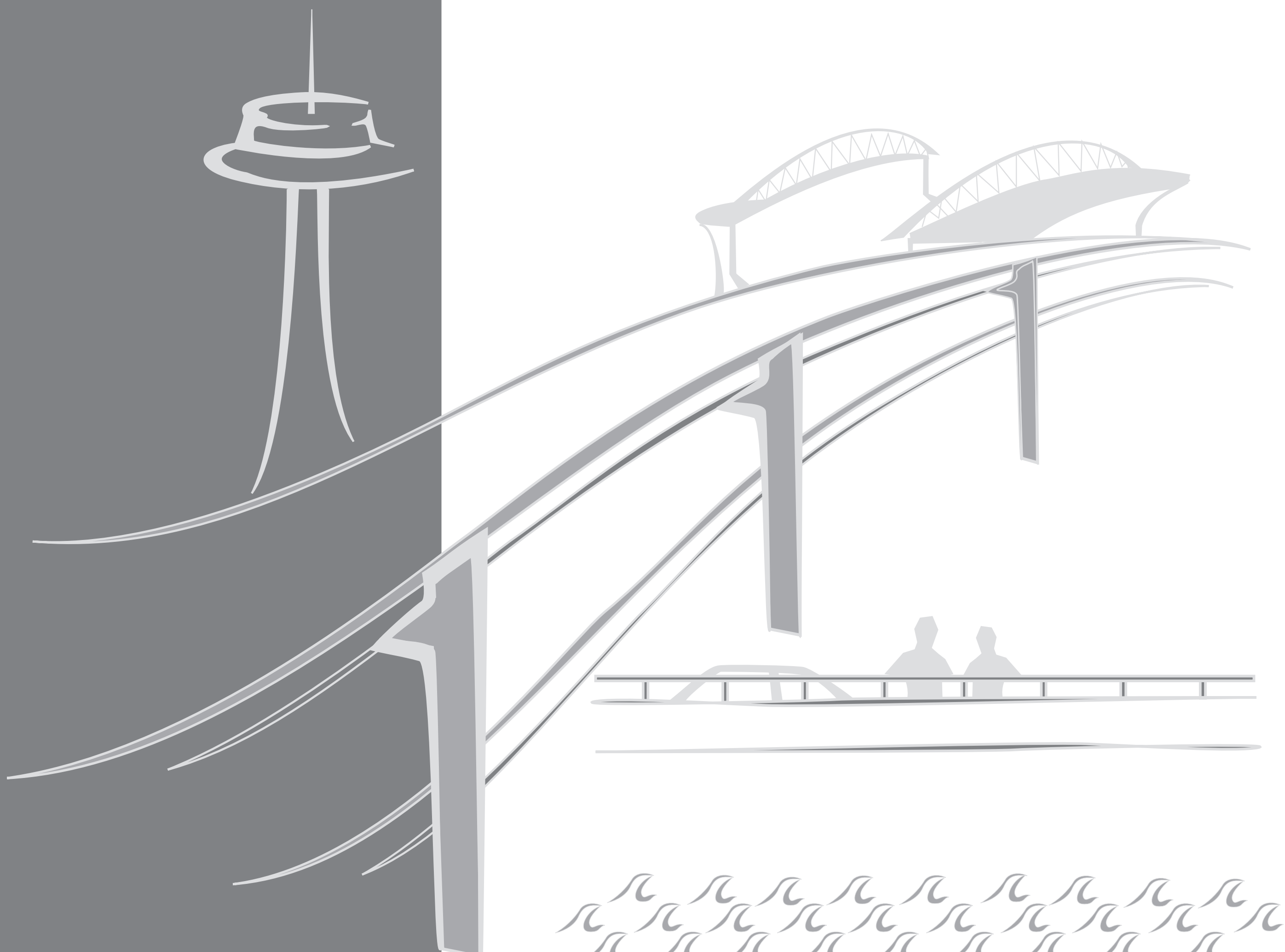
SR 99: ALASKAN WAY VIADUCT & SEAWALL REPLACEMENT PROJECT

Draft Environmental Impact Statement
Appendix V
Energy Technical Memorandum



MARCH 2004

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U.S. Department of Transportation Federal Highway Administration

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SR 99: ALASKAN WAY VIADUCT & SEAWALL REPLACEMENT PROJECT

Draft EIS
Energy Technical Memorandum

AGREEMENT NO. Y-7888

FHWA-WA-EIS-04-01-D

Submitted to:

Washington State Department of Transportation
Alaskan Way Viaduct and Seawall Replacement Project Office
999 Third Avenue, Suite 2424
Seattle, WA 98104

The SR 99: Alaskan Way Viaduct & Seawall Replacement Project is a joint effort between the Washington State Department of Transportation (WSDOT), the City of Seattle, and the Federal Highway Administration (FHWA). To conduct this project, WSDOT contracted with:

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In association with:

BERGER/ABAM Engineers Inc.
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Entech Northwest
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ACRONYMS

BTUs	British Thermal Units
Caltrans	California Department of Transportation
EPA	U.S Environmental Protection Agency
kph	kilometers per hour
kpl	kilometers per liter
MBTUs	million BTUs
mpg	miles per gallon
mph	miles per hour
State Route	SR
SUVs	sport utility vehicles
Tera BTUs	million MBTUs
USDOE	U.S. Department of Energy
USDOL	U.S. Department of Labor
VMT	vehicle miles traveled

Chapter 1 SUMMARY

Energy is consumed during the construction and operation of transportation projects. Energy used during project operation includes fuel consumed by vehicles using the project and a negligible amount of energy for signals, lighting, and maintenance. Fuel consumption depends on the number of vehicle miles traveled (VMT) and travel conditions such as vehicle type, speed of travel, roadway grade, and pavement type. For any given vehicle, speed is the most important factor affecting fuel consumption.

Fuel consumption in the downtown Seattle core in 2030 is expected to range from 93 to 96 thousand gallons per day under the various alternatives. It would be approximately 2 percent greater under the No Build Alternative than under the various Build Alternatives. The total energy used during project operation would be lowest under the Surface Alternative because that alternative would serve less of the transportation demand than the other alternatives. However, although it would use the least energy during operation, the Surface Alternative would result in the highest energy consumption per mile of travel of all the Build Alternatives because of higher congestion and lower average speed. Energy consumption from tunnel ventilation systems would be negligible in comparison to vehicle fuel consumption. Energy consumption differences between the other Build Alternatives would be negligible.

Energy is used during construction to manufacture materials, transport materials, and operate construction machinery. The amount of energy consumed during construction is proportional to the project size. Energy consumed during project construction can be estimated from the construction cost estimate.

Energy would be consumed during construction of any of the Build Alternatives for the Alaskan Way Viaduct and Seawall Replacement Project. Construction of the Tunnel Alternative is predicted to require approximately 67 percent more energy than construction of the Surface Alternative. Construction energy requirements for the other alternatives would be between those estimated for the Surface and Tunnel Alternatives. These values are a small fraction of the energy projected to be consumed in the state of Washington over the approximately 8- to 11-year construction period and would not put substantial additional demand on energy sources or fuel availability in the region.

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Chapter 2 BACKGROUND

The alternatives evaluated for energy consumption are described in Appendix B. Alternatives Description and Construction Methods Technical Memorandum.

Energy is consumed during the construction and operation of transportation projects. It is used during construction to manufacture materials, transport materials, and operate construction machinery. Energy used during project operation includes fuel consumed by vehicles using the project and a negligible amount of energy for signals, lighting, and maintenance. Fuel consumption depends on the VMT and travel conditions such as vehicle type, speed of travel, roadway grade, and pavement type. For any given vehicle, speed is the most important factor affecting energy consumption.

2.1 Energy Units

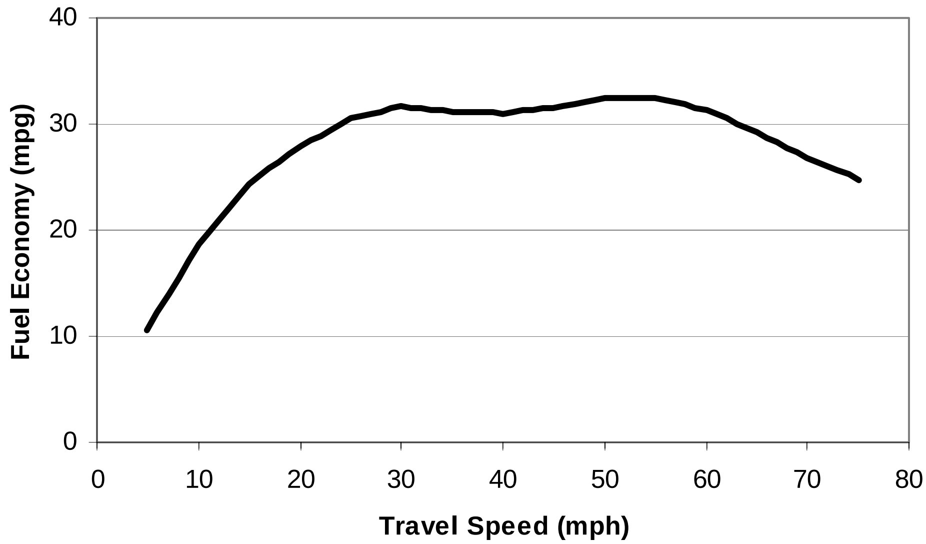
Common units of energy measurement are joules and British Thermal Units (BTUs). Because these are relatively small units, energy is often reported in giga joules (billion joules) and million BTUs (MBTUs). One giga joule is the equivalent of 0.95 MBTUs. Even larger amounts of energy are reported in million MBTUs (Tera BTUs). One liter of gasoline contains approximately 0.03 giga joules of energy (1 gallon = 0.13 MBTUs). As a point of reference, the caloric intake for an adult person is approximately 3 giga joules per year (2,000 Calories = 0.008 giga joules).

2.2 Energy Consumed by Operating Vehicles

The transportation sector is very energy-dependent upon petroleum. Transportation within the United States consumes approximately 27,000 Tera BTUs of petroleum per year and that amount is expected to increase to 44,000 Tera BTUs by 2025 (USDOE 2003a). Gasoline consumption in the United States is projected to increase an average of 2 percent per year over the next two decades.

Vehicle fuel consumption is the primary component of operating costs paid by individual users of transportation facilities. Road geometry, surface conditions, and traffic flows substantially affect the operating efficiency of vehicles, and consequently of total energy consumption.

For the various alternatives, fuel consumption rates can be differentiated by comparing changes in traffic operations, as measured by VMT and changes in traffic speed. Fuel consumption is proportional to distance traveled, and decreases as speed increases up to about 45 kilometers per hour (kph) (30 miles per hour [mph]). Fuel consumption is fairly flat between about 45 kph (30 mph) and 90 kph (60 mph) and increases as speed increases above that point (USDOE 2002) (Exhibit 2-1). Energy consumption is assessed using forecasted volumes and speeds.



Source: Department of Energy, 2002

Exhibit 2-1. Average Automobile Fuel Consumption Compared to Speed

Since the early 1970s, the U.S Environmental Protection Agency (EPA) has analyzed automobile and light truck fuel economy data. Fuel economy continues to be a major area of public and policy interest for several reasons, including:

- Fuel economy is directly related to carbon dioxide emissions, the most prevalent pollutant associated with global warming. Light vehicles contribute about 20 percent of all U.S. carbon dioxide emissions.
- Light vehicles account for approximately 40 percent of all U.S. oil consumption. Crude oil, from which nearly all light vehicle fuels are made, is considered to be a finite natural resource.
- Fuel economy is directly related to the cost of fueling a vehicle and is of greater interest when oil and gasoline prices rise, as has happened recently.

Since 1988, average new light vehicle fuel economy has declined 1.9 mpg, or over 7 percent. This decline has resulted from the increase in the light truck market share and in general vehicle weight and performance (EPA 2003).

Fleet-wide improvement in new light vehicle fuel economy occurred from the mid-1970s through the late 1980s, but has consistently fallen since then. Viewed separately, the average fuel economy for new cars has been essentially flat over the last 15 years, only varying from 27.6 to 28.6 mpg. Similarly, the average fuel economy for new light trucks has been largely unchanged for the past 20 years, ranging from 20.1 to 21.6 mpg (EPA 2003).

The increasing market share of light trucks, which have lower average fuel economy than cars, accounts for much of the decline in fuel economy of the overall new light vehicle fleet. Recent growth in the light truck market has resulted from the popularity of sport utility vehicles (SUVs). SUV sales have increased by more than a factor of ten—from 2 percent of the overall market in 1975 to 20 percent of the market in 2000. Over the same period, the market share for vans doubled from 4.5 to 9 percent, and for pickup trucks grew from 13 to 17 percent. For model year 2000, cars average 28.1 mpg, vans 22.5 mpg, pickups 20.1 mpg, and SUVs 20.0 mpg (EPA 2003).

More efficient technologies, such as engines with more valves and sophisticated fuel injection systems and transmissions with lockup torque converters and extra gears, continue to penetrate the new light vehicle fleet. The trend has clearly been to apply these new technologies to increase average new vehicle weight, power, and performance while maintaining fuel economy. The U.S. Department of Energy (USDOE) projects this trend to continue, with average new car horsepower increasing by 27 percent by 2025, but little change in average fuel economy (Exhibit 2-2).

Nationwide trends over the last 10 to 15 years reflect a lack of progress in fuel economy. New technologies used in hybrid vehicles change the horizon for fuel economy projections and indicate that improvements on the order of 100 to 200 percent may be possible (EPA 2003). Recent developments suggest various potential pathways for possible future fleetwide fuel economy improvements, including voluntary commitments by some manufacturers to improve the fuel economy of certain portions of their fleets by as much as 25 percent. At this point, the USDOE projects that average fuel economy for the total on-road fleet will change little over the next 20 years. Rather, technology improvements will generally result in a larger, more powerful rather than more fuel-efficient vehicle fleet. Trends within the state of Washington are expected to be similar to the national projections.

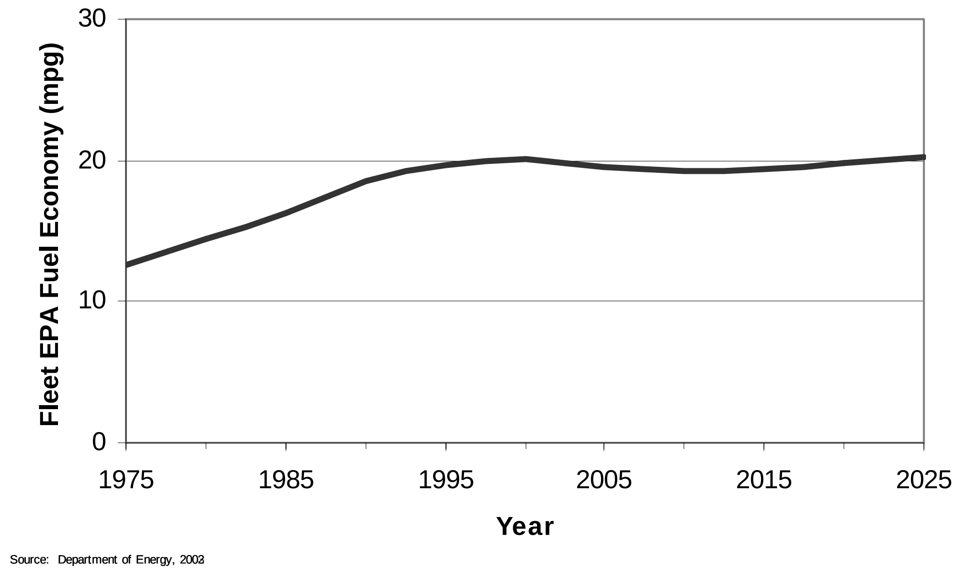


Exhibit 2-2. Fleetwide Fuel Economy Trend

2.3 Energy Consumed for Roadway Operation and Maintenance

Ongoing roadway maintenance consumes energy. The California Department of Transportation (Caltrans) estimates that maintenance activities for urban freeways consume approximately 170 MBTUs per lane-mile per year (Caltrans 1983). Because this value is less than 1 percent of the energy consumption of vehicles traveling over the roadway, it is not included in the comparison of alternatives in this study.

During roadway operation, lighting and traffic signals consume energy. The ventilation system for the upgraded Battery Street Tunnel will consume additional energy under all of the Build Alternatives. Under the Tunnel and Bypass Tunnel Alternatives, the ventilation system for the new waterfront tunnel also would consume energy. The consumption for the upgraded Battery Street Tunnel is estimated to be approximately 4 MBTUs per day (30 five-horsepower supply fans and 6 twenty-six-horsepower jet fans). Approximately 27 million additional BTUs per day would be consumed for ventilation of the Tunnel or Bypass Tunnel Alternatives (16 fifty-horsepower and 12 forty-horsepower fans). These values are approximately 0.25 percent of the estimated daily traffic energy consumption in the study area in 2030. Lighting and ventilation systems would consume energy in the form of electricity. The existing electricity grid is expected to have sufficient capacity to service the project's operational electricity demand.

2.4 Energy Consumed for Roadway Construction

Energy is consumed both directly and indirectly during project construction. Direct energy consumption includes the energy used to operate construction machinery, provide construction lighting, and produce and transport materials such as asphalt. Indirect energy consumption includes activities such as manufacturing and maintaining construction equipment, and the energy consumed by workers commuting to the project site. Because direct one-time energy consumption for roadway projects is much greater than indirect energy consumption and indirect energy consumption is difficult to define, only direct energy consumption is considered in this evaluation (Caltrans 1983). More of the construction energy consumption is in the form of petroleum than electricity.

The energy consumption required to complete a project is proportional to the project size and the nature of the work involved. For projects of a specific type, the energy required for construction is proportional to the project cost, as the project cost is directly related to the project size. As a result, energy consumption for a specific project can be estimated based on its cost and type. Caltrans has developed construction energy factors that were related to 1977 construction dollars (Caltrans 1983). The U. S. Department of Labor (USDOL) tracks a price index for highway and street construction (USDOL 2002). Using the highway and street construction price index, the energy factors can be referenced to year 2002 dollars (Exhibit 2-3). Construction energy consumption factors represent a simplified relationship between project size and energy consumption. The results obtained from their use are not exact, but provide a basis of comparison between alternatives.

Exhibit 2-3. Construction Energy Consumption Factors (2002 Dollars)

Facility Type	Factor (MBTU / thousand dollars)
Rural Freeway	26.5
Rural Conventional Highway	25.2
Rural Freeway Widen	16.5
Rural Conventional Highway Widen	17.8
Urban Freeway	10.5
Urban Conventional Highway	9.6
Urban Freeway Widen	9.4
Urban Conventional Highway Widen	8.9
Interchange	26.8

2.5 Indirect Energy Consumption

In addition to the energy directly consumed by vehicles and used for facility operation and maintenance, transportation systems indirectly consume energy. For example, the manufacturing and routine maintenance of vehicles requires energy. Indirect energy consumption would vary little between the alternatives because construction of one alternative rather than another is not expected to affect people's decisions to purchase new vehicles or have maintenance completed on their current vehicles. Indirect energy consumption includes all forms of energy, as it accounts for manufacturing and maintenance of all resources associated with, but not part of, the facility, such as the tires of cars that drive on SR 99.

Chapter 3 METHODOLOGY

The Alaskan Way Viaduct and Seawall Replacement Project would create the greatest energy demands in the following areas: long-term operational energy consumption related to vehicle travel and short-term construction-related energy consumption. The following methodology was used to estimate this consumption.

3.1 Calculation of Energy Consumed by Operating Vehicles

The analysis of operational energy within the study area is based on the transportation analyses prepared for this project. By using daily VMT and speed values calculated from the transportation forecasting model for the study area, net changes in overall energy consumption caused by operation of the alternatives were assessed.

The energy consumption calculations were made as precisely as possible by calculating the VMT and speed for each of the approximately 1,800 transportation forecasting model links in the study area for three periods each day: AM peak, PM peak, and off-peak. Energy consumption on each link was calculated by multiplying the VMT for each link during each period with the appropriate average vehicle fuel consumption (Exhibit 2-1) for the link's speed. The fuel consumption rate in liters of fuel consumed per kilometer of travel or gallons per mile is the inverse of fuel economy in units of kilometers per liter (kpl) or miles per gallon (mpg).

Link speed for Alaskan Way was updated using Synchro model results, because the network forecasting model estimated speed is not sufficiently sensitive to congested conditions to realistically represent this corridor. Under the Surface Alternative, Alaskan Way was modeled with an average peak-period speed of 9 mph. The other alternatives had an average speed on SR 99 through downtown Seattle in the range of 45 to 50 mph and 25 to 30 mph on the Alaskan Way surface street. The fuel consumption was summed for all links during each time period, and summed for all three time periods to estimate daily fuel consumption.

The alternatives were compared based on daily differences in fuel consumed by traveling vehicles (USDOT 1980). This value is approximate for each alternative and does not account for the energy used for facility maintenance and signal operation. However, it provides a good basis for comparing the alternatives.

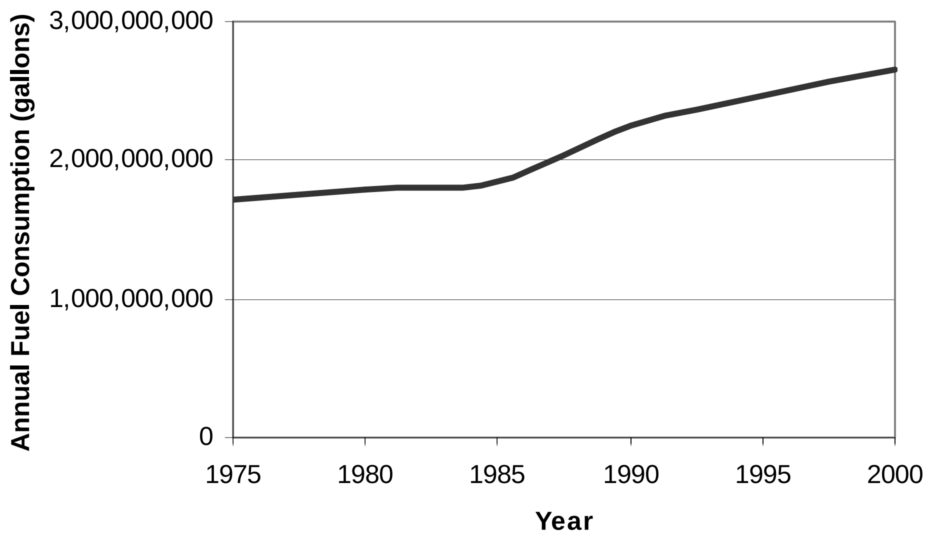
The same fuel consumption rates were used for 2002 and 2030, because of the small projected change in on-road fleet fuel economy between now and 2025

(Exhibit 2-2) and the lack of available projections from 2025 to 2030. If fleet-average fuel economy becomes substantially better by 2030, the operational energy consumption will decrease for all of the alternatives analyzed.

3.2 Calculation of Energy Consumed for Roadway Construction

Construction energy consumption was estimated for each of the alternatives by estimating the energy consumed based on the project's construction cost. The Rebuild, Aerial, and Tunnel Alternatives are most similar to urban freeway construction, and the Surface Alternative is most similar to urban highway construction. An approximate construction energy consumption factor for urban freeway construction (adjusted to year 2002 construction cost dollars) is 10.0 giga joules (10.5 MBTUs) per thousand 2002 dollars of construction cost. For urban highway construction, the factor is 9.1 giga joules (9.6 MBTUs) per thousand 2002 dollars of construction cost (Exhibit 2-3). Construction cost was estimated for the Alaskan Way Viaduct and Seawall Replacement Project using a statistical risk approach. The 90-percent risk cost (the cost at or below which there is a 90-percent chance that the project can be completed) was used to estimate the construction energy consumption.

In the state of Washington, petroleum use accounts for approximately 45 percent of all energy consumption (CTED 2001). Approximately 40 percent of petroleum use is for motor vehicle fuel. In 2000, 329 Terra BTUs of petroleum (10 billion liters or 2.6 billion gallons of fuel) were consumed by motor vehicles in the state of Washington (Exhibit 4-1). Transportation energy consumption increased approximately 2.5 percent annually in the state of Washington during the 1990s. Total statewide annual energy consumption was 2,170 Terra BTUs in 2000 (USDOE 2003b).



Source: Department of Energy, 2003a

Exhibit 4-1. State of Washington Fuel Consumption Trend

4.2 Regional Travel Patterns

In the 1980s in the Puget Sound region, the VMT increased nearly three times faster than population and jobs. From 1981 to 1989, the central Puget Sound region's population increased 15 percent, the number of employed persons increased 34 percent, and the amount of automobile traffic (measured by total VMT) increased 71 percent (PSRC 2000). The high growth rate in VMT during the 1980s was attributed to a large increase in the number of two-worker households during that decade. More recently, traffic in the central Puget Sound region has grown at a similar rate to population and employment. Between 1989 and 1999, population grew 19 percent, employment grew 27 percent, and VMT increased a comparable 26 percent.

The regional daily VMT in 1999 was 65 million miles per weekday (PSRC 2000). The regional daily VMT is expected to increase to 112 million miles per weekday by 2010, but then level off to 94 million miles per weekday by 2030 under the *Destination 2030* plan (PSRC 2001).

4.3 Study Area Characteristics

The project study area evaluated for transportation energy consumption is consistent with the area evaluated in the transportation study. This area includes the portion of the City of Seattle where traffic patterns would most likely be affected by the various project alternatives. The study area encompasses the downtown core and is roughly defined by Elliott Bay on the west, Lake Union on the north, Interstate 5 (included in the study area) on the east, and S. Spokane Street (included in the study area) on the south.

Land use in the study area ranges from low-rise light industrial to high-rise office towers. Transportation-related energy consumption in the study area includes fuel consumed by roadway, marine, and rail transportation. Other energy demand includes electricity, natural gas, and oil to supply a wide variety of commercial businesses, light industry, and residences within the study area.

4.4 Existing Energy Consumption

Currently, approximately 2.4 million vehicle miles are traveled daily within the project study area (Exhibit 4-2). This results in a daily consumption of approximately 299,000 liters of gasoline (79,000 gallons) with an energy content of 10,810 giga joules (10,270 MBTUs).

Exhibit 4-2. Daily Operational Energy Consumption

Alternative	Daily VMT	Average Network Speed (MPH)	Daily Fuel Consumption		Daily Energy Consumption	
			Liters	Gallons	Giga Joules	MBTUs
2002 Existing Conditions	2,378,000	39	299,000	79,000	10,810	10,270
2030 No Build Alternative	2,855,000	37	360,700	95,300	13,030	12,390
2030 Rebuild Alternative	2,852,000	46	353,900	93,500	12,740	12,160
2030 Aerial Alternative	2,863,000	46	354,700	93,700	12,780	12,180
2030 Tunnel Alternative	2,869,000	46	354,700	93,700	12,810	12,180
2030 Bypass Tunnel Alternative	2,861,000	45	354,300	93,600	12,820	12,170
2030 Surface Alternative	2,793,000	44	352,800	93,200	12,800	12,120

Chapter 5 Operational Impacts and Benefits

With the exception of the Surface Alternative, the various alternatives will generally maintain current capacity in the Alaskan Way Viaduct Corridor in different ways. The Surface Alternative would reduce capacity, and this is reflected in the lower daily VMT that would result from less of the transportation demand being served.

Traffic is predicted to increase by the year 2030, independent of construction of this project. Vehicle fuel consumption dominates the energy use for each alternative, and is largely determined by daily VMT and travel speed. Energy consumption resulting from daily vehicle operations in the study area was computed for the No Build Alternative and five Build Alternatives for 2030 (Exhibit 4-2). Increased transit ridership is projected under all of the alternatives, including the No Build Alternative. If transit ridership does not increase as projected, operational energy consumption would be greater than forecasted in this evaluation. Energy consumption from tunnel ventilation systems would be approximately 0.25 percent of vehicle fuel consumption.

Differences in energy consumption under all of the Build Alternatives would be approximately 2 percent less than for the No Build Alternative. Traffic speeds are predicted to be lower under the No Build Alternative than under the Build Alternatives. The total energy used during project operation would be lowest under the Surface Alternative because that alternative would serve less of the transportation demand than the others. However, although it would use the least energy during operation, the Surface Alternative would result in the highest energy consumption per mile of travel of all the Build Alternatives because of higher congestion and lower average speed. Differences between the other Build Alternatives would be negligible (Exhibit 4-2).

The various design options would result in small changes in operational energy consumption. They are not expected to result in energy consumption that is substantially different from the evaluated alternatives.

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Chapter 6 CONSTRUCTION IMPACTS

Under all of the Build Alternatives, energy would be consumed during construction to manufacture materials, transport materials, and operate construction equipment.

For each alternative, the total energy consumption for the approximately 8- to 11-year construction period is presented in Exhibit 6-1. The construction energy consumption would be spread over this period. These values correspond to approximately 0.1 percent of the energy consumed in the state of Washington in 2000. This consumption would not put substantial additional demand on energy sources or fuel availability in the state during the construction period.

Exhibit 6-1. Total Construction Energy Consumption

Alternative	Construction Cost (billion 2002 dollars)	Energy Consumption	
		Giga Joules	MBTUs
No Build Alternative	0	0	0
Rebuild Alternative	2.53	28,000,000	27,000,000
Aerial Alternative	2.40	27,000,000	25,000,000
Tunnel Alternative	3.05	34,000,000	32,000,000
Bypass Tunnel Alternative	2.35	26,000,000	25,000,000
Surface Alternative	2.00	20,000,000	19,000,000

The various design options would result in small changes in construction energy consumption proportional to the change in the quantity of work associated with each option. An aerial structure south of S. King Street could consume up to 2,000,000 additional giga joules or MBTUs compared to the at-grade option. The Seawall Frame Option could consume up to 4,000,000 additional giga joules or MBTUs compared to the Seawall Rebuild. Other design options would result in differences of less than 1,000,000 additional giga joules or MBTUs

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Chapter 7 SECONDARY AND CUMULATIVE IMPACTS

Secondary impacts are the reasonably foreseeable effects of a project that occur later in time or are further removed in distance from its direct effects. Generally, these effects are induced by the initial project. For the Alaskan Way Viaduct and Seawall Replacement Project, secondary impacts are expected to be limited and unlikely because the alternatives would not substantially increase existing capacity or connections.

The cumulative effects of the project alternatives on energy use would be a function of regional vehicle fuel economy, VMT, and operating conditions. Transportation energy use in the Puget Sound region would vary between the alternatives depending on the VMT and travel operations under each of the alternatives (Exhibit 4-2). The values calculated are for the Alaskan Way Viaduct and Seawall Replacement Project study area and include the influence of other projects in the Puget Sound region.

During the construction period, if several other large construction projects are underway in the Puget Sound region, local energy demand could be greater than customarily experienced in the region. This would require an increase in the quantity of energy imported into the region.

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Chapter 8 OPERATIONAL AND CONSTRUCTION MITIGATION

Because the Build Alternatives would result in a decrease in long-term energy use compared to the No Build Alternative, no mitigation would be required. Any transportation control measures to reduce traffic volumes and congestion would also decrease energy consumption. Measures to maintain transportation and construction practices that reduce energy consumption could reduce energy demand during the construction period.

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ATTACHMENT A

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