I-70 Mountain Corridor PEIS Energy Technical Report

August 2010

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Section 1. Purpose of the Report

This *I-70 Mountain Corridor PEIS Energy Technical Report* supports the information contained in **Chapter 3, Section 3.16** of the *I-70 Mountain Corridor Programmatic Environmental Impact Statement* (PEIS). It identifies:

- Methods used to identify energy resources and determine potential impacts of alternatives;
- Consequences of the Action Alternatives evaluated in the I-70 Mountain Corridor PEIS;
- Considerations for energy during Tier 2 Processes; and
- Mitigation strategies.

Section 2. Background and Methodology

Energy is used during the construction and operation of transportation facilities. The energy that is used in the construction of various facilities is inclusive of the manufacture and transport of materials and equipment making up each alternative, as well as the operation of construction equipment. Operational energy consumption is the fuel and electricity used to power the vehicles using the transportation facility. This total energy is based on the vehicle mix and vehicle miles of travel for each alternative being evaluated. The *U.S. Department of Energy Transportation Energy Data Book* (Davis, et al., 2009) provides current vehicle mix and average fuel consumption data to estimate daily transportation energy consumption (use of energy as a source of heat or power or as a raw material input to a manufacturing process). Given average values of energy consumption for various vehicles based on available data, and knowing the number of vehicle miles of travel, it is possible to determine energy consumption per vehicle miles of travel and ultimately per day or per year. This is the approach taken for the Corridor alternatives.

Considerable information is available regarding energy use, both in construction and vehicle operations. Some energy use can be calculated based on actual energy per unit consumed, such as a gallon of gasoline. Considerable information has been recorded by various agencies and has been presented in terms of vehicle miles of travel or person miles of travel. However, differences exist among the various information sources, and an exact estimate of anticipated energy usage in any Action Alternative is not possible nor is it absolutely necessary. Therefore, using available information and adapting it consistently to all Action Alternatives provides a reasonable comparison among alternatives. It should be noted that there are many variables, especially among Transit alternatives, that are difficult to quantify. It is known, for example, that spacing between transit stations can have a substantial effect on energy consumption, even for like vehicle types. Greater spacing reduces energy consumption.

Of particular interest in the Corridor is how the major changes in elevation from Denver to the Continental Divide affect energy consumption. Moving a vehicle from less than 6,000 feet to 11,000 feet involves overcoming an elevation change of approximately 1 mile, at grades as high as 7 percent; this situation has an impact on energy requirements. One cannot necessarily conclude that the additional effort to accomplish uphill climbs is compensated by a corresponding decrease in energy needed on the descent part of the trip, especially as it applies to heavy trucks. However, electrical energy savings can be realized if regenerative braking systems are used on transit vehicles. Although grades were considered in modeling the Transit components, the calculations required to determine energy savings associated with vehicle types are complex and may not result in defensible conclusions. Therefore, a simplistic approach (using data from previous studies) is used to determine energy consumption (construction and operation) of the Action Alternatives, at least as it applies to all nontransit vehicles. These data are then applied to projected construction costs and to the vehicle miles of travel modeled for all alternatives.

To compare energy use among alternatives, energy usage is presented in a common unit of energy. The British thermal unit (BTU) is used as the common unit of energy for this assessment. The British thermal unit is a basic measure of thermal heat energy and is a traditional unit of energy that is approximately the amount of energy needed to heat 1 pound of water to 1 degree Fahrenheit; it is a precise measure of the heat content of fuels.

The project footprint was used to analyze energy consumption. The project footprint includes the physical footprint of the alternatives, plus an additional 30 feet on each side. The 30 feet includes a 15-foot construction disturbance zone and an additional 15-foot sensitivity zone.

2.1 Energy for Construction

Estimating the quantity of BTUs used for construction of transportation facilities is not straightforward. For the Corridor, this assessment is even more complex given the altitude, steep grades, and abbreviated construction seasons that can result in reduced efficiencies. The lead agencies (FHWA and CDOT) used an accepted technique that approximates construction energy usage on the basis of construction cost to develop BTU usage numbers. The project team used a method developed by Engineering News Record and Caltrans (1983) to apply an approximate construction energy consumption factor of 9.48 billion BTUs per million dollars in construction cost. The construction energy consumption factor was adjusted to the year 2000 and was not updated to 2010 because the energy costs to install materials remained constant. This value is based on urban freeway expansion but was deemed reasonable for this Corridor because much of the construction involves complexities that, while not identical to urban situations, would likely expend great amounts of energy. Although this method is relatively old, few quantitative methods have been developed to calculate energy use in construction, and this practice continues to be a recognized and accepted industry standard for calculating energy usage for constructing transportation facilities.

The Caltrans (1983) values were also used to determine energy consumption during construction of transit systems. An estimate of 19.9 billion BTUs per track-mile was used and applied to the Corridor. This includes the installation of track and power systems. For dual track, the factor was doubled, although due to economies of scale, the actual consumption may be less than double. Other civil construction costs associated with Transit alternatives and not directly attributable to transit vehicles, track, and power systems (such as viaducts, walls, or earthwork) were treated the same as highway construction costs in terms of calculating energy consumption. That is, energy consumption for construction of those elements was based on 9.48 billion BTUs per million dollars in construction costs. Therefore, all alternatives having a transit component were evaluated as to their construction energy consumption in terms of both track mileage and construction costs.

Construction costs are based on the 2010 estimated costs of alternatives. Details about the cost estimates and cost estimating process are presented in the *I-70 Mountain Corridor Cost Estimating Technical Report* (CDOT, August 2010).

2.2 Energy for Operations

2.2.1 Highway Alternatives

Operational energy consumption by vehicles operating on the roadway is directly proportional to the number of vehicle miles traveled. Variables include vehicle type, speeds, roadway grades, and fuel economy. Average gas mileage for all vehicles in the traffic stream can be used to convert miles traveled to a measurement of energy. Operational energy consumption for Highway alternatives is calculated by multiplying the BTU per gallon of gasoline by the daily gasoline consumption. Most sources agree that 1 gallon of gasoline is equivalent to about 125,000 BTU (as shown below).

$$\boxed{\text{Number of gallons of gas}} \times \boxed{125{,}000\ \text{BTU}} \times \boxed{\frac{\text{Number of miles traveled}}{\text{Average fuel}}} = \boxed{\text{Operational Energy consumption for Highway alternatives (in BTU)}}$$

Gasoline usage is calculated by dividing the total vehicle miles traveled by the average fuel economy.

The United States Department of Energy has data regarding travel and energy readily available in its *Transportation Energy Data Book* (Davis, et al., 2009). The *Transportation Energy Data Book* includes a table relating passenger travel and energy use in the United States for the year 2008 for various modes of transportation, including automobiles, buses, and rail (Davis, et al., 2009). The information suggests a fuel economy of approximately 22 miles per gallon for cars. **Table 1** presents the energy usage by vehicle type. The energy consumption for automobiles in the report is 5,669 BTU per vehicle mile of travel. This number is consistent with what was calculated, which yielded a rate of 5,682 BTU per vehicle mile of travel.

Table 1. Estimated Energy Use by Vehicle Type

Vehicle Type	Load factor (persons/vehicle)	BTU per passenger mile
Cars	1.59	3437
Personal Trucks	1.84	3647
Motorcycles	1.18	1875
Buses (transit)	9.2	4348
Rail (all types)	26.9	2541

Source: Davis, et al., 2009.

2.2.2 Transit Alternatives

Energy consumption for the transit elements of each Action Alternative was calculated on various bases. Transit energy usage consists of electrical energy expressed in kilowatt-hours and fuel consumption expressed in gallons of diesel fuel. A kilowatt-hour is a unit of energy equal to 1,000 watt hours and is the most commonly known billing unit for energy delivered to consumers by electric utilities. For example, using a 60 watt light bulb for 1,000 hours consumes 60 kilowatt-hours of electricity. All Transit alternatives include a certain amount of diesel fuel consumption. For the Bus in Guideway alternatives, both the diesel bus and the dual-mode bus (off a guideway) would use diesel fuel for propulsion. The Intermountain Connection portion of the Rail with Intermountain Connection Alternative also relies on diesel fuel for propulsion. The Rail with Intermountain Connection and Advanced Guideway System alternatives consume a certain amount of diesel fuel associated with feeder bus components.

Fossil Fuel Use

Total transit energy use per day from fossil fuel sources was calculated using this formula:

$$\text{Guideway Round-Trip Diesel Fuel Use} \times \text{Number of Round-Trips per Day} + \frac{\text{Out-of-Guideway Round-Trip Mileage}}{\text{Fuel Economy}} \times \text{Number of trips per day} = \text{XXX gallons}$$

Round-trip diesel fuel use for the transit alternatives with a guideway was estimated using RAILSIM 7® Train Performance Calculator simulations. This proprietary software was used to model overall train and Dual-Mode Bus in Guideway performance in the Corridor, including speeds, travel time, and energy consumption. The model uses train and bus performance parameters in conjunction with ridership demand.

Round-trip mileage for the transit alternatives that were out-of-guideway was determined from the TransCAD travel demand model, a Geographic Information System (GIS) designed specifically for use by transportation professionals to store, display, manage, and analyze transportation data.

For purposes of determining fuel consumption by the buses off a guideway, a fuel consumption rate of 2.6 miles per gallon was used for the diesel bus including feeders and 2.0 miles per gallon was used for the Dual-Mode bus based on Davis, et al. (2009) fuel economy estimates. Running time and distance for the segments off the guideway were based on simulations conducted using the VISSIM™ software (a general modeling, simulation and control system design application).

The number of round trips per day was determined by operating plans and 2035 ridership projections.

Electric Energy Use

Electric energy use per day was calculated using this formula:

$$\text{Round-Trip Electricity Use} \times \text{Number of Round-Trips per Day} = \text{XXX kWh}$$

Round trip electricity use was estimated by RAILSIM 7® Train Performance Calculator and the Federal Transit Administration's report, *Urban Maglev Technology Development Program—Colorado Maglev Project Report* (Federal Transit Administration, March 2004). The model calculated only the propulsion and on-board energy requirements, not the energy required to levitate the trains. Energy required to levitate the trains was derived from Federal Transit Administration estimates. These values were added as the propulsion energy factors for energy usage estimates calculated by the RAILSIM 7® model.

The number of round trips per day was determined by operating plans and 2035 ridership projections.

The total Transit alternative energy usage was calculated by converting both the fossil fuel and electricity usages to BTU, using 3,412 BTU per kWh of electricity and 139,000 BTU per gallon of diesel fuel (from Davis, et al., 2009).

XXX gallons of diesel fuel (from fossil fuel usage calculation)	X	139,000 BTU	+	XXX kWh of electric usage (from electric usage calculation)	X	3,412 BTU	=	Total energy consumption estimates for transit alternative

2.2.3 Combination Alternatives

Energy usage for the Combination alternatives was calculated by adding together the energy usage for Highway and Transit alternatives as appropriate.

2.3 Cost of Energy

Energy costs associated with the operation of the Action Alternatives were also calculated. Electrical cost rates were based on local prevailing energy rates from Davies et al. (2009). Fossil fuels include coal, petroleum, and natural gas, all of which contain high percentages of carbon. Accordingly, it was assumed that $0.10 per kilowatt-hour of electricity is a reasonable estimate of current rates for this source of energy.

Diesel fuel and gasoline costs are widely variable across the country and fluctuate considerably from week to week and even day to day. To provide a defensible unit cost for these forms of energy, it was decided to use data published by the Energy Information Administration of the United States Department of Energy (United States Department of Energy, November 2009). The Energy Information Administration maintains a website that provides up-to-date costs per gallon for these fuels in various regions of the country, including the Rocky Mountain Region. The Energy Information Administration updates these costs weekly, and costs are continually fluctuating based on market demand and other factors. For the PEIS calculations, updated 2009 costs were used to calculate the cost of energy. Specifically, the week beginning November 2, 2009 for the Rocky Mountain Region are used. These costs were determined to be $2.605 per gallon for gasoline and $2.810 per gallon for diesel. Due to constant fluctuation in diesel fuel and gasoline prices, it is recognized that any attempt to calculate “current” costs will be outdated quickly. The costs, therefore, are intended to be a “ballpark” of the cost of energy of the alternatives and are presented primarily to show the differences among the alternatives, as all alternatives use the same baseline and all are compared to the No Action Alternative. When comparing energy consumption against energy costs, the differences in percentages relative to the No Action Alternative result from variations in electrical versus diesel/automotive fuel usage (and their unit costs) among the alternatives.

Discussion of how gasoline prices affect the traveling public is contained in the *I-70 Mountain Corridor PEIS Social and Economic Values Technical Report* (CDOT, August 2010).

Section 3. Description of Alternatives

This section summarizes the alternatives considered in the I-70 Mountain Corridor PEIS. A more complete description of these alternatives is available in **Chapter 2** of the PEIS and in the *I-70 Mountain Corridor PEIS Alternatives Screening and Development Technical Report* (CDOT, August 2010).

3.1 Minimal Action Alternative

The Minimal Action Alternative provides a range of local transportation improvements along the Corridor without providing major highway capacity widening or dedicated transit components. The Minimal Action Alternative includes elements of the Transportation System Management family and the Localized Highway Improvements family, including: transportation management, interchange modifications, curve safety modifications, and auxiliary lanes. These elements are also incorporated into the other Action Alternative Packages.

3.2 Transit Alternatives

Four Transit alternatives are considered in the PEIS as a reasonable range representing the Fixed Guideway and Rubber Tire Transit families:

- Rail with Intermountain Connection Alternative
- Advanced Guideway System Alternative
- Dual-Mode Bus in Guideway Alternative
- Diesel Bus in Guideway Alternative

3.2.1 Rail with Intermountain Connection

The Rail with Intermountain Connection Alternative would provide rail transit service between the Eagle County Regional Airport and C-470. Between Vail and C-470 the rail would be primarily at-grade running adjacent to the I-70 highway. The segment between Vail and the Eagle Count Airport would be constructed within the existing Union Pacific Railroad right-of-way. A new Vail Transportation Center, including new track, would be constructed between Vail and Minturn to complete the connection between the diesel and electric trains. This alternative also includes auxiliary lane improvements at eastbound Eisenhower-Johnson Memorial Tunnels to Herman Gulch and westbound Downieville to Empire and the other Minimal Action Alternative elements except for curve safety modifications at Dowd Canyon, buses in mixed traffic and other auxiliary lane improvements.

3.2.2 Advanced Guideway System

The Advanced Guideway System Alternative would provide transit service between the Eagle County Regional Airport and C-470 with a 24-foot-wide, 118 mile, fully elevated system. The Advanced Guideway System Alternative would use a new technology that provides higher speeds than the other Fixed Guideway Transit technologies studied for the PEIS. Any Advanced Guideway System would require additional research and review before it could be implemented in the Corridor. Although the Federal Transit Administration-researched urban magnetic levitation system is considered in the PEIS, the actual technology would be developed in a Tier 2 process. This alternative includes the same Minimal Action elements as described previously for the Rail with Intermountain Connection Alternative.

3.2.3 Dual-mode Bus in Guideway

This alternative includes a guideway located in the median of the I-70 highway with dual-mode buses providing transit service between the Eagle County Regional Airport and C-470. This guideway would be 24 feet wide with 3 foot high guiding barriers and would accommodate bidirectional travel. The barriers direct the movement of the bus and separate the guideway from general purpose traffic lanes. While traveling in the guideway, buses would use guidewheels to provide steering control, thus permitting a narrow guideway and providing safer operations. The buses use electric power in the guideway and diesel power when traveling outside the guideway in general purpose lanes. This alternative includes the same Minimal Action Alternative elements as described previously for the Rail with Intermountain Connection Alternative.

3.2.4 Diesel Bus in Guideway

This includes the components of the Dual-mode Bus in Guideway Alternative except that the buses use diesel power at all times.

3.3 Highway Alternatives

Three Highway alternatives are advanced for consideration in the PEIS as a reasonable range and representative of the Highway improvements, including Six-Lane Highway 55 mph, Six-Lane Highway 65 mph, and Reversible/HOV/HOT Lanes. The Highway alternatives considered both 55 and 65 mph design speeds to 1) establish corridor consistency and 2) address deficient areas within the Corridor. The 55 mph design speed establishes a consistent design speed throughout the Corridor, which currently does not exist. The 65 mph design speed further improves mobility and addresses safety deficiencies in key locations such as Dowd Canyon and the Twin Tunnels. Both the 55 mph and the 65 mph design speed options are augmented by curve safety improvements, but the 65 mph design speed constructs tunnels in two of the locations: Dowd Canyon and Floyd Hill/Hidden Valley.

3.3.1 Six-Lane Highway 55 mph Alternative

This alternative includes six-lane highway widening in two locations: Dowd Canyon and the Eisenhower-Johnson Memorial Tunnels to Floyd Hill. This alternative includes auxiliary lane improvements at eastbound Avon to Post Boulevard, both directions on the west side of Vail Pass, eastbound Frisco to Silverthorne and westbound Morrison to Chief Hosa, and the Minimal Action Alternative elements except for buses in mixed traffic and other auxiliary lane improvements.

3.3.2 Six-Lane Highway 65 mph Alternative

This alternative is similar to the Six-Lane Highway 55 mph Alternative; it includes the same six-lane widening and all of the Minimal Action Alternative elements except the curve safety modification at Dowd Canyon. The higher design speed of 65 mph alternatives requires the curve safety modifications near Floyd Hill and Fall River Road to be replaced with tunnels.

3.3.3 Reversible Lanes Alternative

This alternative is a reversible lane facility accommodating high occupancy vehicles and high occupancy toll lanes. It changes traffic flow directions as needed to accommodate peak traffic demands. It includes two additional reversible traffic lanes from the west side of the Eisenhower-Johnson Memorial Tunnels to just east of Floyd Hill. From the Eisenhower-Johnson Memorial Tunnels to US 6, two lanes are built with one lane continuing to US 6 and the other lane to the east side of Floyd Hill. This alternative includes one additional lane in each direction at Dowd Canyon. This alternative includes the same Minimal Action Alternative Elements as the Six-Lane Highway 55 mph Alternative.

3.4 Combination Alternatives

Twelve Combination alternatives, combining Highway and Transit alternatives are considered in the PEIS. Four of these alternatives involve the buildout of highway and transit components simultaneously. Eight alternatives include preservation options, the intent of which is to include, or not preclude, space for future modes in the I-70 Mountain Corridor. The Combination alternatives all include the Six-Lane Highway 55 mph Alternative for highway components.

Combination Rail and Intermountain Connection and Six-Lane Highway Alternative—This alternative includes the 55 mph six-lane highway widening between Floyd Hill and Eisenhower-Johnson Memorial Tunnels, the Rail and Intermountain Connection transit components, and most of the components of the Minimal Action Alternative. The exception is that only one of the Minimal Action auxiliary lane improvements (from Morrison to Chief Hosa westbound) is included.

Combination Advanced Guideway System and Six-Lane Highway Alternative—This alternative includes the 55 mph six-lane highway widening between Floyd Hill and Eisenhower-Johnson Memorial Tunnels and the Advanced Guideway System transit components. It includes the same Minimal Action Alternative elements as the Combination Rail and Intermountain Connection and Six-Lane Highway Alternative.

Combination Bus in Guideway (Dual-Mode) and Six-Lane Highway Alternative—This alternative the 55 mph six-lane highway widening between Floyd Hill and Eisenhower-Johnson Memorial Tunnels and the dual-mode bus in guideway transit components. It includes the same Minimal Action Alternative elements as the Combination Rail and Intermountain Connection and Six-Lane Highway Alternative.

Combination Bus in Guideway (Diesel) and Six-Lane Highway Alternative—This alternative includes the 55 mph six-lane highway widening between Floyd Hill and Eisenhower-Johnson Memorial Tunnels and the diesel bus in guideway transit components. It includes the same Minimal Action Alternative elements as the Combination Rail and Intermountain Connection and Six-Lane Highway Alternative.

Combination Rail & Intermountain Connection and Preservation of Six-Lane Highway Alternative—This alternative includes the Rail and Intermountain Connection Alternative and preserves space to construct the Six-Lane Highway 55 mph at a later point.

Combination Advanced Guideway System and Preservation of Six-Lane Highway Alternative—This alternative includes the Advanced Guideway System and preserves space to construct the Six-Lane Highway 55 mph at a later point.

Combination Bus in Guideway (Dual-Mode) and Preservation of Six-Lane Highway Alternative—This alternative includes the Combination Bus in Guideway (Dual-Mode) Alterative and preserves space to construct the Six-Lane Highway 55 mph at a later point.

Combination Bus in Guideway (Diesel) and Preservation of Six-Lane Highway Alternative—This alternative includes the Bus in Guideway (Diesel) Alternative and preserves space to construct the Six-Lane Highway 55 mph at a later point.

Combination Preservation of Rail and Intermountain Connection and Six-Lane Highway Alternative—This alternative includes the Six-Lane 55 mph Highway Alternative and also preserves space to construct the Rail and Intermountain Connection at a later point.

Combination Preservation of Advanced Guideway System and Six-Lane Highway Alternative— This alternative includes the Six-Lane 55 mph Highway Alternative and also preserves space to construct the Advanced Guideway System at a later point.

Combination Preservation of Bus in Guideway (Dual-Mode) and Six-Lane Highway Alternative— This alternative includes the Six-Lane Highway Alternative and also preserves space to construct the Bus in Guideway (Dual-Mode) at a later point.

Combination Preservation of Bus in Guideway (Diesel) and Six-Lane Highway Alternative—This alternative includes the Six-Lane Highway Alternative and also preserves space to construct the Bus in Guideway (Diesel) at a later point.

3.5 Preferred Alternative—Minimum and Maximum Programs

The Preferred Alternative provides for a range of improvements. Both the Minimum and the Maximum Programs include the Advanced Guideway System Alternative. The primary variation between the Minimum and Maximum Programs is the extent of the highway widening between the Twin Tunnels and the Eisenhower-Johnson Memorial Tunnels. The Maximum Program includes six-lane widening between these points (the Twin Tunnels and the Eisenhower-Johnson Memorial Tunnels), depending on certain events and triggers and a recommended adaptive management strategy.

3.6 No Action Alternative

The No Action Alternative provides for ongoing highway maintenance and improvements with committed funding sources highly likely to be implemented by the 2035 planning horizon. The projected highway maintenance and improvements are committed whether or not any other improvements are constructed with the I-70 Mountain Corridor project. Specific improvements under the No Action Alternative include highway projects, park and ride facilities, tunnel enhancements, and general maintenance activities.

Section 4. Environmental Consequences

This section discusses energy consumption for each Action Alternative. Energy impacts include energy consumed by vehicles using the facility and energy used during construction activities within the Corridor. The long-term issues of energy consumption rates, the predicted increase in worldwide petroleum demand, the status of oil supplies, and fluctuating fuel costs are issues are of a national and global nature and, therefore, not unique to the I-70 Mountain Corridor and not used to compare Action Alternatives.

4.1 Construction Impacts

Energy is consumed by operation of construction equipment, as well as delivery of materials to the site. The amount of energy consumed during construction was calculated on the basis of construction costs, as well as the number of track miles for Transit and Combination alternatives, as earlier described. Construction costs were not calculated for the No Action Alternative because construction expected under the No Action Alternative would also be included in the Action Alternatives. No construction energy usage, therefore, is a more appropriate baseline to compare energy usage of the Action Alternatives. It should be noted that the energy consumption numbers are one-time values and are not time dependent on when the construction takes place and/or its duration. Preservation options are included in **Table 2** and have different assumptions in construction energy usage because in some cases, no energy would be used (if only land adjacent to the highway is acquired but no construction is required), but in other cases, construction would occur outside of the right-of-way to accommodate transit options in the I-70 highway median.

The Minimal Action, Six-Lane Highway (55 or 65 miles per hour [mph]), and Reversible/High Occupancy Vehicle (HOV)/High Occupancy Toll (HOT) Lanes alternatives are anticipated to have the lowest total construction energy consumption. Less overall construction requires fewer materials and, therefore, less energy consumption. The Preferred Alternative, Advanced Guideway System, Combination Six-Lane Highway with Advanced Guideway System, and Combination Six-Lane Highway with Rail and Intermountain Connection alternatives are anticipated to have the highest total construction energy consumption. **Table 2** summarizes the estimated construction energy consumption for each alternative.

Table 2. Construction Energy Consumption, in Billion BTU

Alternative	Number of Transit Track Miles	Civil Construction Energy Consumption	Track Construction Energy Consumption	Total Construction Energy Consumption
No Action	N/C	N/C	N/C	N/C
Minimal Action	N/A	12	N/A	12
Rail with Intermountain Connection	147	26	3	29
Advanced Guideway System	236	43	5	47
Bus in Guideway (Dual-Mode and Diesel)	N/A	36	N/A	36
Six-Lane Highway 55 mph	N/A	19	N/A	19
Six-Lane Highway 65 mph	N/A	22	N/A	22
Reversible/HOV/HOT Lanes	N/A	20	N/A	20
Combination Six-Lane Highway with Rail and Intermountain Connection	147	48	3	51
Transit with Highway Preservation	147	46	3	49
Highway with Transit Preservation	N/A	26	N/A	26
Combination Six-Lane Highway with Advanced Guideway System	236	67	5	71
Transit with Highway Preservation	236	65	5	69
Highway with Transit Preservation	N/A	25	N/A	25
Combination Six-Lane Highway with Bus in Guideway (Dual-Mode and Diesel)	N/A	46	N/A	46
Transit with Highway Preservation	N/A	43	N/A	43
Highway with Transit Preservation	N/A	25	N/A	25
Preferred Alternative[1]	N/A to 236	58 to 67	N/A to 5	58 to 71

[1]The Preferred Alternative is presented as a range because the adaptive management component allows it to be implemented based on future needs and associated triggers for further action. Chapter 2, Section 2.7 of the I-70 Mountain Corridor PEIS describes the triggers for implementing components of the Preferred Alternative.

Key to Abbreviations/Acronyms

BTU= British thermal units HOT=High Occupancy Toll HOV=High Occupancy Vehicle
mph = miles per hour N/A = not applicable N/C = not calculated

4.2 Operational Impacts

Energy use during operations of any alternative are directly related to the gasoline and diesel consumption of automobiles, trucks, and buses, as well as to the propulsion energy generated for powering transit vehicles. The total energy consumption was calculated on the basis of annual vehicle miles of travel for each mode and alternative, reduced to an average daily rate, as previously described. The variations among the alternatives are small enough to have little to no effect on total energy usage or fuel availability along the Corridor or in the region.

For the first tier level of analysis, how energy would be supplied to the Corridor (e.g., fuel distribution or electrical generation capacity) was not considered; it was simply assumed that buses would be fueled at garages supplied by a fuel distributor and that electricity would be supplied through the existing power grid. The analysis did consider, however, high-voltage power transmission capacity and infrastructure expansion that may be required through placement of transmission lines and appropriately spaced substations along the Corridor. Power travels from the power plant to the substations through a system called the power distribution grid, which can be aboveground or underground.

Table 3 summarizes daily operational energy consumption for each Action Alternative. If the No Action were selected, no action would be taken therefore no energy usage would be associated with the No Action, which would be an appropriate baseline to compare energy usage of the Action Alternatives. The preservation options are not included in the calculations of operational energy use because no vehicles would operate within the preserved corridor. Vehicle miles traveled on the roadway represents the great majority of impacts in terms of energy usage. The variation in total operational energy consumption among the Action Alternatives, as compared to the No Action Alternative, ranges from no change for the Rail with Intermountain Connection and Advanced Guideway System alternatives to 17 percent higher in the case of the Combination Six-Lane Highway with Diesel Bus in Guideway Alternative. The Preferred Alternative is among the lowest of all alternatives, with expected increases ranging between 6 percent and 7 percent over the No Action Alternative by 2035.

Table 3. Daily Operational Energy Consumption – Based on 2035 Travel Demand

Alternative	Total Transit Energy Use per Day (kWh)	Total Transit Energy Use per Day (Gallons)	Daily Transit Energy Consumption (Billion BTU)	Daily Vehicle Miles on Roadway	Daily Gasoline Consumption (Gallons)	Total Daily Energy Consumption (Billion BTU)	Total Daily Energy Operations Cost[1]	Change in Energy Consumption Relative to No Action	Change in Energy Cost Relative to No Action
No Action	N/A	N/A	N/A	7,937,501	360,796	45.1	$939,872	N/A	N/A
Minimal Action	N/A	10,307	1.43	7,886,351	358,470	46.2	$962,778	3%	2%
Rail with Intermountain Connection	353,893	5,611	1.99	7,602,796	345,582	45.2	$951,396	0%	1%
Advanced Guideway System	480,505	1,691	1.87	7,577,457	344,430	44.9	$950,042	0%	1%
Dual-Mode Bus in Guideway	419,317	6,084	2.28	7,657,130	348,051	45.8	$965,702	2%	3%
Diesel Bus in Guideway	N/A	43,159	5.99	7,668,452	348,566	49.6	$1,029,291	10%	10%
Six-Lane Highway (55 and 65 mph)	N/A	N/A	N/A	8,906,240	404,829	50.6	$1,054,580	12%	12%
Reversible/HOV/HOT Lanes	N/A	N/A	N/A	8,916,457	405,293	50.7	$1,055,790	12%	12%
Combination Six-Lane Highway with Rail and Intermountain Connection	382,036	5,907	2.12	8,164,669	371,121	48.5	$1,021,573	8%	9%
Combination Six-Lane Highway with Advanced Guideway System	501,607	1,691	1.95	8,119,072	369,049	48.1	$1,016,284	7%	8%
Combination Six-Lane Highway with Dual-Mode Bus in Guideway	334,464	6,886	2.09	8,132,914	369,678	48.3	$1,015,751	7%	8%
Combination Six-Lane Highway with Diesel Bus in Guideway	N/A	45,913	6.38	8,179,969	371,817	52.9	$1,097,598	17%	17%
Preferred Alternative[2]	501,607 to 501,969	1,690 to 1,691	1.95	8,077,130 - 8,119,072	367,142 - 369,049	47.8 to 48.1	$1,011,351 to $1,016,284	6% to 7%	8%

Note: The preservation alternatives are not listed here because they would have the same energy consumption as their respective base alternatives.

[1]Electrical energy cost for transit is based on $0.10 per kWh. Diesel energy costs for transit and gasoline cost for cars are based on per gallon costs for the Rocky Mountain Region as posted on the United States Department of Energy, Energy Information Administration, website (http://www.eia.doe.gov/oog/info/gdu/gasdiesel.asp), accessed November 2, 2009.

[2]Some of the values for the Preferred Alternative are presented as a range because the adaptive management component allows it to be implemented based on future needs and associated triggers for further action. Chapter 2, Section *2.7 of the I-70 Mountain Corridor PEIS describes the triggers for implementing components of the Preferred Alternative.*

Key to Abbreviations/Acronyms

BTU = British thermal units HOV = High Occupancy Vehicle HOT = High Occupancy Toll kWh = kilowatt hours N/A = not applicable

4.3 Impacts in 2050

By 2050, the decreased availability of fossil fuels is likely to affect travel. Potential effects include a change of fuel type, resulting in more hybrids and electrically powered vehicles. Reductions in supply could also result in changes in public policy such as introducing carbon or vehicle miles of travel taxes, which could decrease travel overall. Reductions in fossil fuel supply could also result in dramatically increased fuel costs, which could decrease travel overall. Therefore, based on available information about fossil fuel availability, vehicle technology advancements, and the trends from 2035 data related to traffic flow improvement from the Action Alternatives, the Preferred Alternative would continue to be among the lowest of all Action Alternatives in operational energy consumption. Because construction of the Preferred Alternative would occur over a longer period of time (2050 rather than 2035), energy impacts from construction would be more spread out over time.

4.4 Other Issues

Peak oil is a term that refers to the global peak in oil production, which occurs when the amount of oil produced worldwide reaches a peak and starts declining. Predictions for when this peak will occur are controversial and range from now to 2035 and beyond. There are also those who believe the peak has already been reached. This decline in oil production does not signify ‘running out of oil’ but it does mean the end of cheap oil, which will have worldwide consequences. Since peak oil is an issue of national and global importance, this topic has not been and will not be used in Tier 2 processes as a comparative feature of Action Alternatives.

4.5 Tier 2 Considerations

The Colorado Department of Transportation will conduct more detailed analyses of energy impacts during future project-specific Tier 2 processes. The most current data and guidance available regarding technology, worldwide petroleum demand, the status of fuel supply, costs, public policy, environmental controls, changing economies, and world markets will be used. Tier 2 processes will include additional analysis of construction and operational impacts based on the specific improvements and mode(s) selected. For this report, fossil fuel was the primary fuel source considered when calculating energy consumption, however, the lead agencies recognize that technologies may advance as could energy consumption data and these potential changes have been considered as part of the evaluations. Tier 2 processes will also have further consideration and analyses of power sources, mixes of energy supply types (such as, renewable/alternative energy and fossil fuel), and other future concepts as is appropriate at that time. Tier 2 processes will also include development of specific best management practices for each project.

Section 5. Mitigation Strategies

5.1 Mitigation Strategies

Mitigation strategies for energy impacts will be developed and refined during Tier 2 processes in the context of a specific project. However, mitigation strategies that typically apply to reduce impacts are addressed below. Construction and operational impacts will be mitigated through implementation of appropriate best management practices.

Conceptual techniques for mitigation of construction impacts could include the following:

- Limiting the idling of construction equipment;
- Encouraging employee carpooling or vanpools for construction workers;

- Encouraging the use of the closest material sources (for example, aggregate, concrete);
- Locating construction staging areas close to work sites;
- Using cleaner and more fuel-efficient construction vehicles (for example, low sulfur fuel, biodiesel, or hybrid technologies);
- Using alternative fuels and asphalt binders; and
- Implementing traffic management schemes that minimize motorist delays and vehicle idling.

Conceptual techniques for mitigation of operational impacts could include the following:

- Carrying out maintenance activities during periods of reduced traffic volumes;
- Encouraging greater use of transit through measures such as incentive programs;
- Working with chambers of commerce or tourist organizations to encourage resort operators to offer incentives for visitors who use transit or who use low emission or alternative fuel vehicles; and
- Promoting carpooling for regular facility users.

Section 6. References

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