4.9 Energy Requirements and Conservation Potential

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This section provides information on the energy requirements of the TAPS and the associated marine transportation link. Comparative data on energy efficiency are provided for other modes of transportation.

4.9.1 TAPS Energy Usage

TAPS carries oil from Pump Station 1 on the edge of the Alaska North Slope (ANS) oil fields south some 800 miles to Valdez. The system requires energy to run the pump stations along the pipeline, support Valdez Marine Terminal (VMT) operations, and for miscellaneous other activities/functions (e.g., lighting, heat, air conditioning, other machinery). Two major energy sources are used for TAPS:

- Fuel gas is carried from North Slope fields to fuel pump stations (Pump Stations 1 through 4) north of the Brooks Range. The fuel gas is transported in a 149-mile long fuel gas line of varying diameter (between 8 and 10 inches).
- Liquid turbine fuel is used to fuel pump stations south of the Brooks Range and to power electrical generators at various places in the system (including those at pump stations and VMT). The liquid turbine fuel is purchased from commercial fuel vendors and delivered in tank trucks.[1] (A small amount of commercial electrical power is purchased at Pump Stations 8, 9, and 12.)[2]

TAPS pioneered the use of drag reducing agent (DRA — a long-chain hydrocarbon polymer injected into the oil to reduce the energy loss due to turbulence in the oil), having first injected DRA at Pump Station 1 on 1 July 1979 (APSC, 1999c). DRA injection facilities are located at Pump Stations 7 and 9, and at Milepost 238 (see Section 2.2). As the name implies, use of DRA reduces the drag, permitting more oil throughput at any given pumping horsepower. Thus, use of DRA conserves energy. The amount (and location) of DRA to be injected is determined by an economic balance between the cost of the DRA and the cost of operating pump stations.

In 1999 (Johnson, J., 2000, pers. comm.), Alyeska Pipeline Service Company (APSC) consumed 7.776 billion standard cubic feet (scf) of fuel gas, purchased 46 million gallons of turbine fuel, and 0.585 million gallons of DRA.

4.9.2 Energy Intensity

Based on the above energy usage figures and traffic, the estimated *energy intensity,* measured in British Thermal Units per ton-mile of crude oil transported (BTU/ton-m)— a standard benchmark used to measure the energy intensity of freight transport — for TAPS was approximately 280 BTU/ton-m, as shown in the calculation detailed in Table 4.9-1. (Data on the heat content of various fuels can be found in ORNL, 1999).

Figure 4.9-1 shows the average energy intensity for various modes of freight transport (ORNL, 1999) in the United States in 1997, including crude and product pipelines, waterborne commerce, Class 1 railroads, and motor freight. Crude oil is shipped by all these transportation modes in the United States. Figure 4.9-2 shows the relative shares (in ton-miles) of crude and refined products carried by each mode over the period from 1977 to 1997 (Association of Oil Pipelines, 1999). In 1997, the respective modal shares were pipeline (64.45 percent);[3] water carrier (30.90 percent); truck (2.90 percent); and rail (1.75 percent). As a practical matter, most crude and product shipments are made via pipeline and ship or tug and barge.

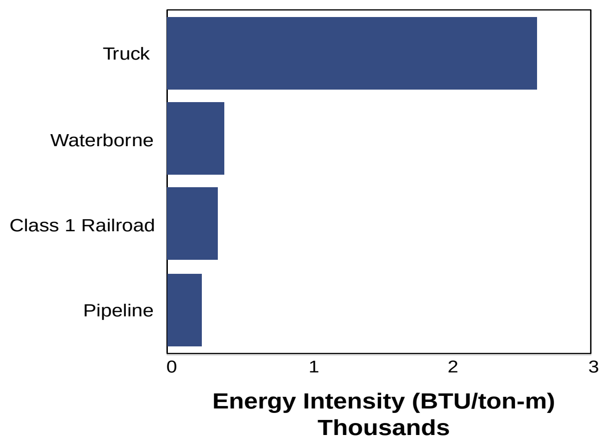
[1]At one time *topping units* were used. A topping unit is a mini-refinery that draws crude off the line and produces turbine fuel to power the pump station. Topping units were used at Pump Stations 6, 8, and 10, but all were placed in standby during 1996 (PS 8, 10) or 1997 (PS 6).

[2]Pump Stations 1, 3, 4, 7, 9, and 12 are presently in operation. As part of the rampdown plan (see Section 2.2) several of these pump stations will be shut down in the coming years.

[3]For crude oil shipments, 69.3 percent of the total ton-miles was carried in pipelines, 30.3 percent by water carriers, 0.3 percent by motor carriers, and only 0.1 percent by rail.

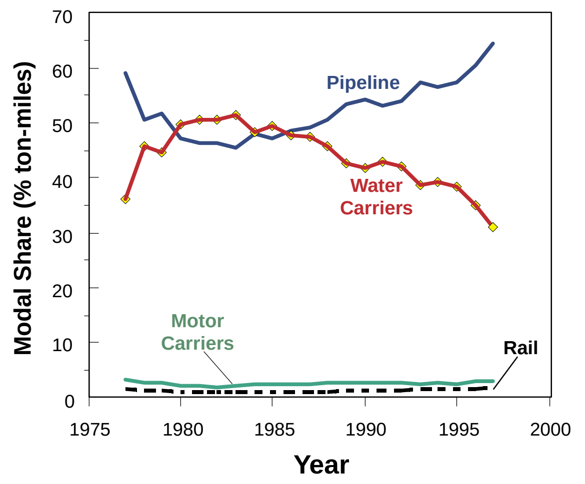
Table 4.9-1. *Energy intensity, BTU/ton-m for TAPS, 1999.*

Item	Units	Value	Source
Fuel gas consumption	scf	$7.776 \times 10^{+9}$	Alyeska for year 1999
Heat content natural gas	BTU/scf	1,031	ORNL (1999, Table B-1)
Gas energy input	BTU	$8.017 \times 10^{+12}$	Multiplication
Turbine fuel usage	gal	$4.60 \times 10^{+7}$	Alyeska for year 1999
Heat content crude	BTU/gal	$1.318 \times 10^{+5}$	ORNL (1999, Table B-1)
Crude energy input	BTU	$6.063 \times 10^{+12}$	Multiplication
Annual throughput	bbl	$4.4 \times 10^{+8}$	Alyeska for year 1999
Unit conversion	bbl/ton	$7.0 \times 10^{+0}$	APSC (1999c)
Annual throughput	tons	$6.3 \times 10^{+7}$	Division
Average haul distance	miles	800	TAPS length, neglects minor offtakes
Annual traffic	ton-m	$5.0 \times 10^{+10}$	Product of annual throughput (tons) and haul distance
Energy consumption	BTU/ton-m	160	Gas
Energy consumption	BTU/ton-m	121	Turbine fuel
Energy consumption	BTU/ton-m	81	Total



Source: ORNL (1990, Table 2-13)

Figure 4.9-1. *Energy intensity for freight shipments, 1997. Crude oil and product pipelines are relatively efficient.*



Source: Association of Oil Pipelines (1999)

Figure 4.9-2. *Crude oil and product shipments in the United States by mode. Pipelines have the largest share (percent of ton-miles).*

As shown in Figure 4.9-1, pipelines are relatively energy efficient when compared to other transportation modes, a finding confirmed by several studies (Hooker, 1981, 1982; Kennedy, 1993; ORNL, various; DOT, 1994).

Considering only pipelines, energy efficiency is a complex function of throughput, capacity, elevation gradient along the pipeline, pipeline diameter, use of DRA, crude or product viscosity and density, temperature and temperature gradient, type of pumps (e.g., electric versus turbine), and other factors (Hooker, 1981, 1982; Kennedy, 1993; Uren, 1953; Cookenboo, 1955). For example, other factors held constant, energy intensity is lower (i.e., the pipeline is *more* energy efficient) the greater the diameter of the pipeline.[4] TAPS is a large diameter pipeline, but employs turbines rather than electric pump motors, crosses three mountain ranges and is presently operated well beneath capacity. Overall, the energy intensity for TAPS in 1999 (280 BTU/

[4]Kennedy (1993) reports that energy consumption for crude oil ranges from about 550 BTU/ton-mile for a 6-inch-diameter pipeline to about 180 BTU/ton-mile for a 40-inch-dameter pipeline.

ton-m) is comparable to that for the average of domestic crude and product pipelines (300 BTU/ton-m).[5]

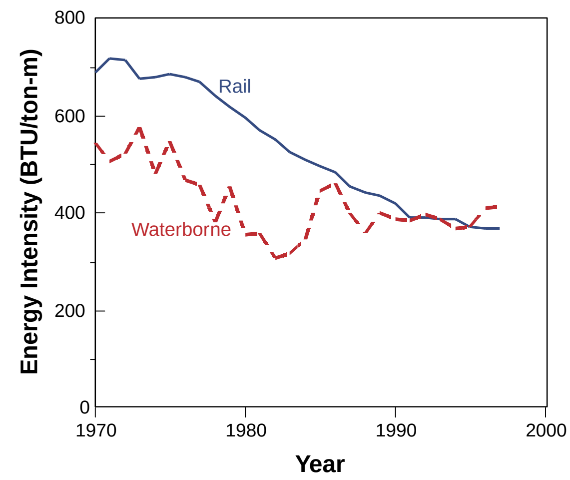
4.9.3 Marine Transportation

No discussion of TAPS energy efficiency would be complete without mention of the marine transportation link. Although a small amount of North Slope oil is exported to Asian ports, the majority is shipped from VMT to ports on the U.S. West Coast and Hawaii. Illustrative haul distances for ANS crude are: Valdez to Port Angeles, WA, 1,200 nautical miles; Valdez to Long Beach, CA, 2074 nautical miles; Valdez to Barber's Point, HI, 3,421 nautical miles.

Data on the energy intensity (BTU/ton-m) of waterborne commerce in the United States are readily available (e.g., DOT, 1994; ORNL, various). For example, Figure 4.9-3 shows the time trend in energy intensity for both rail and waterborne commerce from 1970 to 1997. Although the time series for waterborne commerce is more variable than that for railroads, both modes have become more energy efficient over this period. In 1997, the energy intensity for domestic waterborne commerce averaged approximately 415 BTU/ton-m, slightly less efficient than that for pipelines generally or for TAPS in particular.

One difficulty with the data shown in Figure 4.9-3 is that these are year-to-year averages for all waterborne commerce, including the contribution of oceangoing tankers, coastal tankers, integrated tank barges (ITB), and various tug-barge combinations, carrying both crude and product. These energy intensity averages are not likely to be representative of the energy efficiency of vessels engaged in the ANS trade. Just as there are economies of scale with respect to capital and operating costs of tankers (see, e.g., NRC, 1991, 1998), so too are there economies of scale with respect to energy intensity (USDOE, 1994). Tankers engaged in the ANS trade are larger on average than those engaged in product shipping.

However, there is no readily available statistical compilation of energy efficiency data for vessels engaged in the ANS trade. Accordingly, a series of calculations is made to provide a plausible range of estimates. Table 4.9-2 contains two sets of calculations of energy intensity of tankers of various sizes:



Source: ORNL (1999).

Figure 4.9-3. *Time trends in energy intensity (BTU/ton-m) for rail and waterborne commerce.*

- Table 4.9-2a presents estimates of cruising speed and fuel consumption for double-hull tankers of three sizes taken from an earlier NRC study (NRC, 1991). Calculated energy intensities based on these estimates range from 35 BTU/ton-m to 67 BTU/ton-m. As expected, larger tankers are more energy efficient.
- Table 4.9-2b presents estimates of cruising speed and fuel consumption for the same size tankers as given in Table 4.9-2a based on a 1994 Department of Energy study on the effects of lifting the export ban on ANS crude (USDOE, 1994). This study was based upon actual data supplied by experts from the U.S. Maritime Administration (MARAD). Calculated energy intensities based upon these estimates range from 74 BTU/ton-m to 202 BTU/ton-m, depending upon tanker size. In accord with the results given in Table 4.9-2a, larger tankers are more energy efficient.

Data on cruising speed and fuel consumption are presented for the 120,357 deadweight ton (DWT) *Arco Anchorage* (one of the vessels in the ANS trade) in one recent book (Nadler, 1994). Based on a quoted fuel burn rate of 31,000 gallons/day and a cruise speed of 16 knots for this steam turbine-powered ship, an energy intensity of 81 BTU/

[5]According to data from ORNL, the estimated energy intensity for crude and product pipelines in 1997 was 252 BTU/ton-m. Although estimates of energy intensity are calculated for each year by ORNL, the time series is not useful because no recent data are available on total energy consumption of crude and product pipelines. Therefore, ORNL (Davis, 2000, pers. comm.) simply assumes that total energy consumption of these pipelines is the same as that estimated years ago and calculates energy intensity by dividing this consumption estimate by the ton-m of crude and product traffic. The most recent independent estimate of energy intensity was made in the early 1980s (Hooker, 1981, 1982; Kennedy, 1993; DOT, 1994) and was approximately 300 BTU/ton-m on average.

Table 4.9-2a. *Calculation of energy intensity for oil tankers based on data published by the National Research Council.*

Item	Units	Value			Source/Remarks
Vessel DWT	tons	40,000	80,000	240,000	NRC (1991) for double-hull tanker
Fuel consumption	tons/day	25	45	75	NRC (1991) for double-hull tanker
Fuel heat content	BTU/gal	138,400	138,400	138,400	ORNL (1999, Table B.1)
Fuel heat content	BTU/ton	$4.4645 \times 10^{+7}$	$4.4645 \times 10^{+7}$	$4.4645 \times 10^{+7}$	Conversion
Fuel input	BTU/day	$1.1161 \times 10^{+9}$	$2.0090 \times 10^{+9}$	$3.3484 \times 10^{+9}$	Fuel consumption times heat content
Speed average	knots	15	15	14.6	NRC (1991) for double-hull tanker
Statute miles/day	miles/day	414	414	403	Conversion
Traffic	ton-m/day	$1.66 \times 10^{+7}$	$3.31 \times 10^{+7}$	$9.67 \times 10^{+7}$	DWT times daily advance
Energy intensity	BTU/ton-m	67	61	35	Calculation

Table 4.9-2b. *Calculation of energy intensity for oil tankers based on data published by the U.S. Department of Energy.*

Item	Units	Value			Source/Remarks
Vessel DWT	tons	40,000	80,000	240,000	NRC (1991) for double-hull tanker
Fuel rate	$/sea day	5,625	5,625	12,000	USDOE (1994)
Fuel cost	$75/metric ton	75	75	75	USDOE (1994)
Fuel consumption	tons/day	75	75	160	Calculation
Fuel heat content	BTU/gal	138,400	138,400	138,400	ORNL (1999, Table B.1)
Fuel heat content	BTU/ton	$4.4645 \times 10^{+7}$	$4.4645 \times 10^{+7}$	$4.4645 \times 10^{+7}$	Conversion
Fuel input	BTU/day	$3.3484 \times 10^{+9}$	$3.3484 \times 10^{+9}$	$7.1432 \times 10^{+9}$	Fuel consumption times heat content
Speed average	knots	15	15	14.6	NRC (1991) for double-hull tanker
Statute miles/day	miles/day	414	414	403	Conversion
Traffic	ton-m/day	$1.66 \times 10^{+7}$	$3.31 \times 10^{+7}$	$9.67 \times 10^{+7}$	DWT times daily advance
Energy intensity	BTU/ton-m	202	101	74	Calculation

Table 4.9-3. Energy requirements as percentage of energy shipped (based on one ton of crude transported).

Item	Units	Value	Source/Remarks
Throughput	tons crude	1	Basis for calculation
Heat content	BTU/gal	131,800	ORNL (1999, Table B-1)
Unit conversion	gal/bbl	42	APSC (1999c)
Unit conversion	bbl/ton	7.07	APSC (1999c)
Heat content	BTU	39,136,692	Heat content of crude shipped
Pipeline energy intensity	BTU/ton-m	280	TAPS estimate
Land haul distance	statute miles	800	TAPS length
Pipeline energy required	BTU	224,000	Product of energy intensity, load, and length
Marine transport energy intensity	BTU/ton-m	80	Midpoint of range given in text
Haul distance	NM	2,074	Valdez to Long Beach, CA
Haul distance	statute miles	2,385	Unit conversion
Tanker energy required	BTU	190,808	Product of energy intensity, load, and length
Total energy required	BTU	414,808	Sum of pipeline and tanker transportation
Required as percentage of load	%	1.06	Total energy required divided by heat content of crude

ton-m can be calculated. Estimates based on information from these various sources are not identical, but all point to energy intensities less than 100 BTU/ton-m,[6] approximately four times as efficient as the value estimated for all waterborne commerce. Thus, onward ocean shipping from VMT is assumed to have an energy requirement ranging from 60 BTU/ton-m to 100 BTU/ton-m.

4.9.4 Synthesis

The energy requirements for shipping crude along the pipeline average 280 BTU/ton-m in 1999. Onward shipment of ANS crude from VMT to U.S. West Coast ports probably requires between 60 BTU/ton-m and 100 BTU/ton-m.

Table 4.9-3 provides an illustrative calculation of the energy required to ship one ton of crude oil the length of the TAPS pipeline and then onward via tanker from Valdez, AK, to Long Beach, CA (nearly 2,400 statute miles distant). The energy intensity assumed for the pipeline is 280 BTU/ton-m and for that ocean transit the midpoint of the range of estimates provided above, 80 BTU/ton-m. This trip would require 414,808 BTU, approximately 1.06 percent of the energy contained in one ton of crude. Thus, the energy penalty for transportation is quite small.

For the proposed action, future energy requirements are likely to be similar to those in the recent past. TAPS operators have a strong economic incentive to conserve energy. In the past, TAPS operators implemented DRAs to minimize the amount of energy spent on moving the oil through the pipeline. When throughput decreased, pump stations that were no longer necessary were shut down. Due to the economic incentive, fuel conservation strategies will continue in the future.

For the no-action alternative, the ANS fields, pipeline, and marine transportation system would be shut down and dismantled. Additional oil would have to be imported from foreign sources to make up for the shortfall caused by cessation of ANS production (unless a national conservation policy is implemented to reduce consumption). Energy requirements of the TAPS pipeline and the marine transportation link would be reduced to zero. However, energy would still be required to supply incremental foreign imports. Transportation energy requirements would vary depending upon the origin of these incremental crude oil imports. Transportation energy requirements are unlikely to be appreciably smaller than those at present. TAPS energy efficiency is approximately equal to the average for domestic pipelines, as are marine transportation efficiencies.

[6]The calculated range is 35 BTU/ton-m to 202 BTU/ton-m. However, the average size tanker engaged in the ANS trade is close to 120,000 DWT.