

Report No. S3

Crude Petroleum National Totals

1. Definition of the Commodity Flow Data Gap

1.1. General Description

The general transportation logistics of the petroleum industry include the initial gathering of crude oil in production fields for domestic sources and from marine terminals for foreign imports. Crude petroleum is delivered to refineries or to long-term storage facilities such as the Strategic Petroleum Reserve. From these refineries, finished products are moved to markets throughout the nation.

Transportation of crude petroleum is accomplished by a variety of land- and marine-based modes. They include: pipeline, railroad tanker cars, tanker trucks, barges, and oceangoing tankers. On a volume basis, pipelines and marine vessels are predominately used in transporting petroleum, but trucks also play an essential function.

The Commodity Flow Survey (CFS) does not cover oil and gas extraction industries within NAICS code 211; thus, crude petroleum is out-of-scope.

1.2. Commodities involved in the data gap

1.2.1. SCTG codes

Crude Petroleum is defined under the two-digit SCTG code 16 - Crude Petroleum Oil. This is an out-of-scope commodity for the 2002 CFS.

1.2.2. STCC codes

Under STCC coding, crude petroleum is included in “13 - Crude Petroleum, Natural Gas, or Gasoline”

1.3. Establishments involved in the data gap

1.3.1. NAICS codes

211 - Oil and Gas Extraction
486 - Pipeline Transportation

Both NAICS categories were excluded from the CFS 2002 sampling frame. This is an out-of-scope data gap for CFS.

1.3.2. NAICS-SIC conversion issues

There are no major NAICS-SIC conversion issues for this data gap because crude petroleum is out-of-scope for the CFS. Crude petroleum has been a problem area for the CFS caused by reasons unrelated to establishment definitions (i.e. NAICS verses SIC). The NAICS-SIC conversion does affect, to a certain extent, some data on hazardous materials such as fuel oil, gasoline, and propane that are transported by the highway mode.

2. Importance of the Data Gap

2.1. Value and tonnage as a share of national shipments

Based on information obtained from several sources (discussed in Section 3 of this report), in 2002 a total of 285 billion ton-miles of domestic crude petroleum oil were shipped in the United States. This is about 9% of the total ton-miles reported in the CFS 2002 (about 3,138 billion ton-miles). The total tonnage of crude petroleum in 2002 is estimated at approximately 899 million tons, worth about \$141 billion. Compared to the total tonnage of commodities captured by CFS 2002 (which is 11,668 million tons), crude petroleum clearly is a significant out-of-scope data gap for the CFS (nearly 8%). Although crude's share by value is not as high as that in tonnage, it is almost 2% of the CFS total - when comparing the \$141 billion of crude petroleum to the \$8,397 billion captured by the CFS.

2.2. Value and tonnage as a share for individual modes

Based on ton-miles, pipelines carry approximately 91%, while waterways carry approximately 7.5% of total crude oil movements. Motor carriers carry a small amount of the total, approximately 0.9%.

2.3 Geographic concentration: Dispersed versus concentrated, local versus long distance

Crude petroleum shipments are transported long-distance via pipeline to various locations in the United States. According to the *Pipeline Economics, Oil & Gas Journal*, the average pipeline shipment length is about 230 miles. This study found the average distance for pipeline shipments to be 255 miles and the average distance for all transport modes to be 318 miles.

2.4 Importance to international trade

Imported crude oil is a large part of the total crude processed in the 144 operating refineries across 33 states. On average, 9,140 thousand barrels per day of crude

petroleum were imported during 2002. A very small amount of crude petroleum (9 thousand barrels per day) was exported from the United States in 2002. Domestic crude oil production averaged about 5,746 thousand barrels a day during 2002. More than 60 percent of U.S. refinery inputs are from imported crude petroleum.

The Energy Information Administration (EIA) reports that the nation's dependency on foreign crude petroleum has continued to increase in recent years (see www.eia.doe.gov/)

3. Data Sources

3.1. Coverage in CFS

CFS does not include SCTG code "16 – Crude Petroleum Oil."

3.2. Coverage in other data sources

Basic information on crude production, imports, exports, and disposition at refineries is collected by EIA within the U.S. Department of Energy (DOE). EIA's information on crude petroleum imports and exports at ports can be supplemented by the *Annual Imports and Exports Waterborne Databanks*, prepared and maintained by the Maritime Administration Office of Statistical and Economic Analysis in the U.S. Department of Transportation (DOT).

National level crude oil shipment information by transportation mode is based on *Shifts in Petroleum Transportation* published annually by the Association of Oil Pipelines. This report's modal information in ton-miles is based on several other data sources, including:

- Oil Pipelines: Annual Report (Form 6) of oil pipeline companies provided to the Federal Energy Regulatory Commission.
- Water Carriers: *Waterborne Commerce of the United States*, U.S. Army Corps of Engineers, Part 5, Table 2-2.
- Motor Carriers: *Petroleum Tank Truck Carriers Annual Report*, American Trucking Association, Inc. and *Petroleum Supply Annual*, U.S. DOE, EIA, Volume 1, Table 46.
- Railroads: *Carload Waybill Statistics*, Report TD-1, USDOT, Federal Railroad Administration and *Freight Commodity Statistics*, Association of American Railroads, Table A3.

3.3. Data quality

Data sources listed above are all government published statistics. They are expected to be reliable.

3.4. Other issues

None.

4. Estimation Methods

4.1. General description of alternative methods

Crude oil information collected by EIA provides a starting point for estimating crude oil movements as required by the FAF. The origins of crude petroleum oil include domestic production by state and imports by Petroleum Administration for Defense (PAD) Districts¹. Imports can be further disaggregated to the seaport level with information from MARAD. Destination information is provided for the Strategic Petroleum Reserve (SPR),² refinery inputs (at 12 Refining Districts level), and exports. Similar to imports, exports are also reported at the PAD level, but can be disaggregated to the seaport level using MARAD data.

4.2. Method for estimating national totals

Table 1 (below) contains a national summary of regional estimates of Crude oil movements described in this report. Our estimates show that about 6 billion barrels of Crude Oil, equal to about 824 million tons, were delivered by pipeline in 2002³ based on data from the Federal Energy Regulatory Commission (FERC) Form 6 database. National Waterborne Commerce data from the Corp of Engineers show Crude oil movements on the waterway at about 86 million short tons in 2002. However, the aggregate of state-level Waterborne Commerce data for 2002 is about 68 million short tons. This state-level aggregate is shown in Table 1. Crude oil movement by truck was derived from Table 46 of the Energy Information Administration (EIA) Petroleum Supply Annual 2002. In total, it is estimated that about 899 million tons of Crude oil movement in 2002. The value of crude oil was calculated by multiplying

¹ Petroleum Administration for Defense (PAD) Districts are geographic aggregations of the 50 States and the District of Columbia into five districts. These districts were originally defined during World War II for purposes of administering oil allocation.

² The Strategic Petroleum Reserve is a large-scale crude stockpile program managed by the U.S. Department of Energy. Most stockpiles are stored in underground salt caverns. These stocks are maintained by the Federal Government for use during periods of major supply interruption.

³ 1 ton of crude oil is equal to 7.3 barrels.

the tonnages by the average price of domestic and free-on-board cost of imported Crude oil.

Table 1: National Summary of Crude Oil Movement Estimates by Mode

	Tons (Thousands)	Ton-Miles (Millions)	Value (Million \$)
Pipeline	823,669	209,736	129,316
Waterborne	67,757	74,534	10,638
Rail	0	0	0
Truck	7,778	1,322	1,221
Total	899,204	285,592	141,175

4.3. Method for estimating regional flows

The approach employed for deriving regional estimates of Crude oil movements is a combination of bottom-up and top-down approaches. Data on Crude oil movements were collected from publicly available sources. The pipeline and waterborne data were available at the state-level, while the only sources available for rail and truck were national totals. In the case of rail, Waybill data that are available at the FAF region level did not show any movement of Crude oil. For those sources that have less regional detail than the FAF regions, different methods were employed to disaggregate the resulting estimates to the FAF level.

Available Data for 2002

- a. The Energy Information Administration (EIA) has data on inter-PADD Crude oil movements in Tables 32-35 in Volume 1 of the Petroleum Supply Annual 2002. PADD (Petroleum Administration for Defense Districts) are five groups of states delineated during World War II to facilitate oil allocation. These are shown in Tables 1 and 2 below.

Table 1. EIA Inter-PADD Crude Oil Movement by Pipeline for 2002
(Thousand Barrels)

	From				
	1	2	3	4	Total
1	0	2,479	0	0	2,479
2	0	0	654,447	32,747	687,194
3	3,043	12,159	0	8,112	23,314
4	0	11,901	0	0	11,901
5	0	0	0	0	0
Total	3,043	26,539	654,447	40,859	724,888

Table 2. Inter-PADD Crude Oil Movement by Tanker and Barge for 2002
(Thousand Barrels)

	From				Total
	1	2	3	5	
1	0	2,842	1,002	0	3,844
2	0	0	0	0	0
3	0	0	0	0	0
5	0	0	0	0	0
Total	0	2,842	1,002	0	3,844

- b. Waterborne Commerce data produced by the Corps of Engineers contain origin-destination data at the state level for crude oil movements by waterway.
- c. Crude oil movement by rail can be extracted from the Waybill database. An examination of records for SCTG 16 (Crude oil) from this database shows no movement of Crude oil on the railway.
- d. The Federal Energy Regulatory Commission (FERC) collects data from Crude oil pipeline operators under its jurisdiction (Form 6). The statistics of operations section of this form requests data on receipts and deliveries of Crude oil by state and company.
- e. The Association of Oil Pipelines (AOPL) estimated ton-miles of Crude oil movement by mode for the entire United States (AOPL, 2005).

Methodology

Since the most detailed regional classification in the above datasets is at the state level, an attempt was made to consolidate these into a state level Origin-Destination matrix by mode. The EIA and AOPL include Pipelines, Waterway, Truck and Railroads as Crude oil movement modes in the databases mentioned above.

- a. **Railway:** Both the AOPL (AOPL, 2005) and EIA (Table 46, Petroleum Supply Annual, 2002) data suggest a small amount of Crude oil movement by rail. However, the Railway Waybill data show no interstate movements. The size of movements recorded by the AOPL and EIA are small, less than 0.1 percent and about 8 million barrels, respectively.
- b. **Waterway:** Waterborne Commerce data is a complete enumeration of state-to-state Crude oil movements. As such, there is no additional processing required for this data. An interesting check is to compare the inter-PADD movement by tanker and barge from the EIA to the inter-PADD aggregation of the waterborne data for Crude oil. As shown in Table 2 the EIA data show movements of 2.8 million

barrels and 1 million barrels between PADDs 2 and 1, and PADDs 3 and 1, respectively. An aggregation of the Waterborne Commerce data on the other hand shows no records of inter-PADD movements. As in the case of railways the difference between these two sources is small when compared to the about 450 million barrels of waterborne interstate crude oil movements in 2002. We note that the national number given in the Waterborne Commerce database is about 25 percent greater than computed by aggregating the state data. State-based data in this report were used. In addition, the waterborne commerce data is recorded in short tons. As a result, the waterborne commerce data is deflated to derive the metric ton equivalent. For ton-miles, average miles per ton were derived from the national data to get an estimate of about 1,100 miles.

- c. **Pipeline:** The FERC Form 6 database provides the most comprehensive data on interstate pipeline movement of Crude oil. However, not all pipeline movements are covered in this database. The AOPL estimated the coverage at 84 percent. Although this data show Crude oil receipts and deliveries by state and company, there is no explicit O-D combination data. In order to derive a state-to-state matrix of flows from the available data, an entropy maximization approach was employed to synthesize the available information (see Appendix A). However, before carrying out this exercise a number of adjustments were made to the data:

State Designation: State designations for 55 of the 280 records in the database were problematic and dropped. Of this, 11 records had a blank state field, 4 had Canada, 16 had Federal waters/Offshore, while others simply had “Deliveries,” “International Boundary” or other problems with the state field. These records represent about 2 billion barrels of the around 8 billion barrels of Crude oil received/delivered in the database. Although this is about 25 percent, it is noted that most of these movements occurred at or near the U.S. boundary. In fact, records with a boundary-related state field accounted for about 1.2 billion barrels of receipts and about 500 million barrels of deliveries, while those with a blank state field accounted for 300 million barrels of receipts and 1 billion barrels of deliveries in the database.

Under Coverage: As noted above the AOPL estimated that 16 percent of petroleum pipeline companies are excluded from the Form 6 database. These are companies not required to complete Form 6 because they had operating revenues of less than \$500,000 in any of the previous three years, and are likely to be small intra-state companies. The average operating revenue for companies included in the Form 6 database is about \$50 million. This implies, assuming equal prices per unit oil moved by all companies, that the excluded companies’ scale of operation is only about 1 percent of the average company captured in the Form 6 database. As a result, an estimate of the size of pipeline oil movement not included in the database can be approximated as:

$$0.16 \times 0.01 \times A = 0.0016 \times A$$

where A is the size of oil moved by all companies included in the Form 6 database. A correction factor of 0.002 was used and applied to the data after dropping the records described in (i) above.

Once the above corrections were made, the approach described in Appendix A was applied to derive a state-to-state matrix. The average miles were calculated from the Form 6 database based on total barrels and barrel-miles reported by each company. This was then included in the calculation to simultaneously derive barrel and barrel-mile estimates for our state-to-state matrix. A comparison of the PADD level aggregation of the generated matrix (Table 3) with EIA inter-PADD movements shows that the resulting matrix is quite close to the EIA data. The only discrepancies between the two tables are: 1) The presence of movements from PADD 1 to 2 which is zero in the EIA data, and 2) The movement from PADD 4 to 2 in the generated table is about three times that in the EIA table.

Table 3. Generated Crude Oil Movement by Pipeline at the PADD Regional Level for 2002 (Thousand Barrels)

	From					Total
	1	2	3	4	5	
1	74	2,479	0	0	0	2,553
2	2,479	1,552,136	775,192	108,607	0	2,438,414
3	3,043	12,159	2,287,604	8,112	0	2,310,918
4	0	11,901	0	134,340	0	146,241
5	0	0	0	0	577,888	577,888
Total	5,596	1,578,675	3,062,796	251,059	577,888	5,476,012

Note: This table also includes intra-PADD movements on the diagonal

A final adjustment to the generated state-to-state matrix would be to correct for movements represented by the 55 records dropped from the database. This adjustment was not deemed necessary because most of the movements involved are boundary-related, and would be better treated under imports and exports. In addition, once these movements reach their first destination in the United States any further domestic movements are already captured in the Form 6 database.

- d. **Truck:** The only basis available for estimating Crude oil movement by truck are Table 46 of the Petroleum Supply Annual which showed refinery receipts by truck at about 51 million barrels, and the AOPL which estimated total ton-miles by truck at 0.5 billion. Dividing the AOPL ton-mile number by the tonnage equivalent of the EIA number gives about 170 miles as the average miles of Crude oil truck movement suggesting that these movements are short-hauls. Based on this we allocate the PADD-level EIA numbers to FAF regions based on refinery capacity data by county location, and assume further that such movements are within the FAF region in which the refinery is located. As a result

the FAF-to-FAF truck movement of Crude oil is represented by a diagonal matrix. We use the average mileage calculated above to derive ton-miles.

4.4. Expected quality of the estimates

The estimates are based on government data sources and, therefore, are expected to be reliable.

5. Implications for the Scope and Content of the 2007 CFS

There are multiple agencies that collect crude petroleum supply, disposition, and movement information. However, crude oil transportation statistics are not collected at a level of detail suitable for most transportation analysts. The proposed methodology can be used to generate reasonably reliable estimates of crude petroleum flow over different transportation networks.

Therefore, it is recommended that the CFS 2007 should not change its sample frame to include crude petroleum movements.

6. Other Issues

None.

7. References

Association of Oil Pipelines (AOPL), "Pipeline and Water Carriers Continue to Lead All Other Modes of Transport in Ton-Miles Movement of Oil in 2003, Report, Washington D.C., May 16 2005

Corps of Engineers (COE), 2002 State to State Commodity Movements from the Public Domain Database (Text format). Downloaded from the Web July 2005
<http://www.iwr.usace.army.mil/ndc/db/wcsc/pdomain/data/>

Energy Information Administration (EIA), Petroleum Supply Annual 2002, Volume 1

Federal Energy Regulatory Commission (FERC) Form 6 Database Software. Downloaded July 2005 from <http://www.ferc.gov/docs-filing/eforms/form-6/viewer-instruct.asp>

Appendix A:

Derivation of State to State Pipeline Crude Oil Movement from FERC Form 6 Data

The objective is to derive a matrix of state-to-state Crude Oil movement by pipeline. This objective was formulated as a maximum entropy problem subject to the following conditions based on information from both the FERC Form 6 database and the EIA.

- 1) Sum of deliveries in the generated matrix must equal that in the Form 6 database by state.
- 2) Sum of receipts in the generated matrix are less or equal to than in the Form 6 database by state
- 3) Since receipts and deliveries by state are given by company, a redistribution of state receipts and deliveries to company must meet the same criteria as in (1) and (2) at the company level.
- 4) The generated matrix must minimize the difference between its inter-PADD aggregation and the inter-PADD pipeline movement contained in the database.
- 5) Since actual distance of interstate pipeline movements are not available the generated matrix is required to minimize the distance between states based on Great Circle centroid-to-centroid state distances.

Constraints 1 and 2 were implemented as ordinary constraints; constraint 3 was formulated as a maximum entropy problem and included in the objective function along with the primary objective. Constraints 4 and 5 were implemented by also including in the objective function the square of the differences to be minimized.