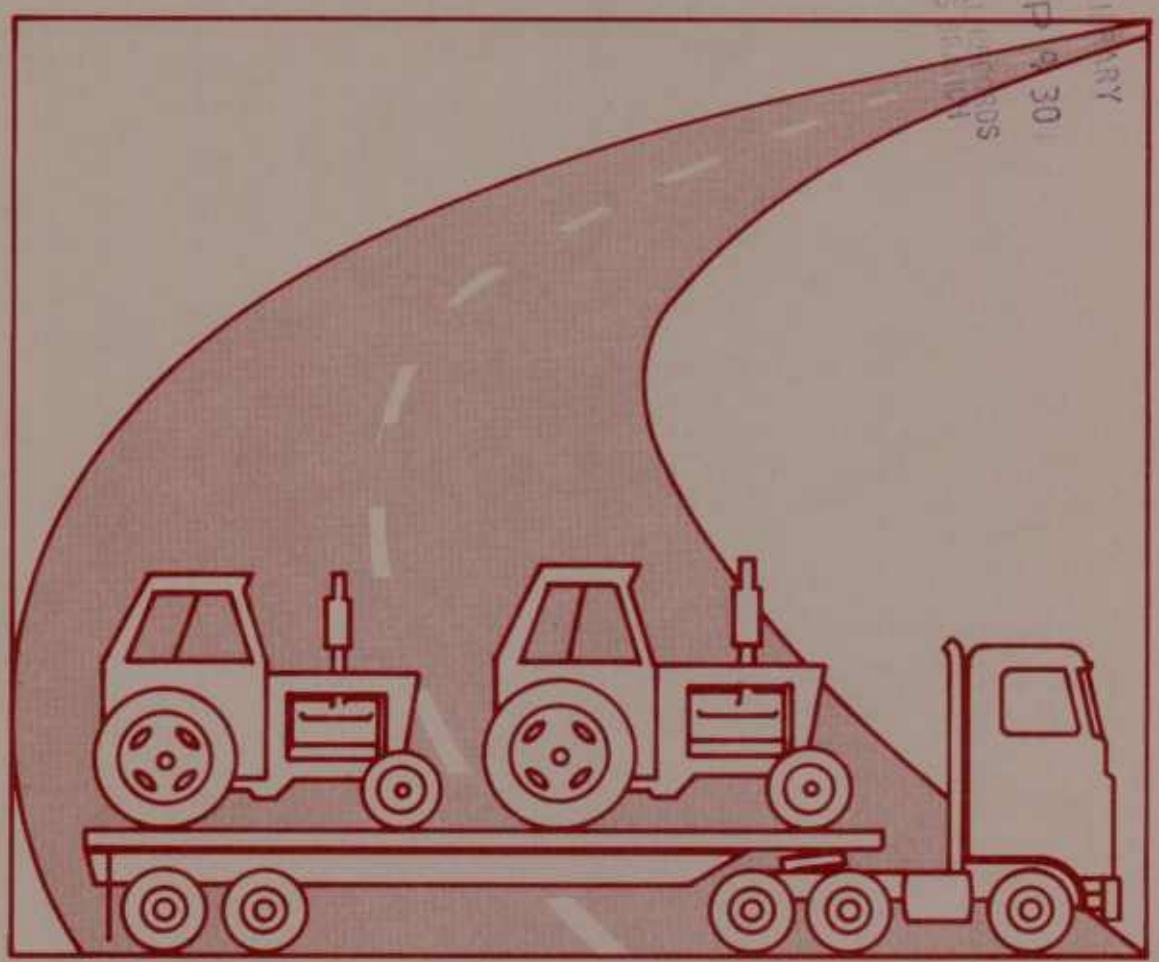
Transportation Fuel Requirements in the Food and Fiber System

John A. Barton



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ABSTRACT

It took an estimated 2,892 million gallons of diesel fuel and 411 million gallons of gasoline to transport farm inputs, commodities, and manufactured food products in 1977. Truck shipments made up 41 percent of total ton-miles in the food and fiber system and required 2,529 million gallons of petroleum fuels, or 77 percent of the total. Rail movements required 665 million gallons of fuel, or 20 percent. Barge shipments accounted for most of the remainder. Demands for transportation fuel in the food and fiber system are likely to continue to increase in the foreseeable future.

Keywords: Transportation, Energy, Diesel fuel, Gasoline, Farm inputs, Agricultural products, Manufactured foods.

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SUMMARY

Continued spot shortages of diesel fuel and gasoline could disrupt the flow of food and fiber from farmers to consumers. It took an estimated 2,892 million gallons of diesel fuel and 411 million gallons of gasoline to transport farm inputs, commodities, and manufactured food products in 1977. Demands for transportation fuel are likely to increase in the foreseeable future.

Transportation of farm inputs required 619 million gallons of fuel. The biggest user of this was the distribution of fertilizer products, which required 195 million gallons. Moving agricultural commodities from farmers to processors required 1,416 million gallons of fuel. The biggest requirements were 654 million gallons for grains and soybeans and 525 million gallons for fruits and vegetables. It took 1,268 million gallons of fuel to transport manufactured food products from processors to warehouses and supermarkets.

Truck shipments made up 41 percent of total ton-miles in the food and fiber system in 1977 and required 2,529 million gallons of fuel, or 77 percent of the total. Rail movements required 665 million gallons, or 20 percent. Barge shipments accounted for most of the remainder.

Transportation fuel requirements for different products can vary by region, season, and year. Variations can be large on the local level because of regional specialization in production, yield changes, and market considerations. Fruits and vegetables going to processors are the most seasonal of the major commodities, while animal products and manufactured food products exhibit no significant seasonal shipping patterns. Variability in grain, soybean, fruit, and vegetable production has the greatest impact on fuel requirements.

Transportation Fuel Requirements in the Food and Fiber System

*John A. Barton**

INTRODUCTION

Transportation services in the food and fiber system provide the vital link between farmer and consumer, moving products from the farm to the grocer's shelf. The transportation industry, in turn, is almost totally dependent upon petroleum fuels to operate the trucks, trains, and barges that transport farm inputs, food, and fiber. The oil embargo of 1973 and more recent gasoline and diesel fuel shortages demonstrated the delicate balance between petroleum fuel supplies and the needs of various industries and consumers. Spot shortages of gasoline and diesel fuel likely will persist over the next several years, and such shortages could disrupt the flow of food and fiber from farmers to processors and from processors to consumers.

Decisionmakers need a clear understanding of transportation fuel requirements of the food and fiber system to make informed policy decisions regarding gasoline and diesel fuel use. This report develops estimates of fuel consumed in 1977 to transport agricultural production inputs, commodities, and manufactured food products. These estimates would be most useful in giving policymakers and the public an idea of the magnitudes of fuel quantities involved, of the relative amounts of fuel required by different products, of the importance of different transport modes, and of some of the seasonal, yearly, and regional variations that might be expected.

Fuel estimates reported here should be used as indices of fuel requirements rather than as point estimates. The timeliness of 1977 estimates in 1980 should not be of serious concern. The transportation and marketing infrastructure is generally not subject to drastic change over short periods of time. The most important variable affecting fuel requirements is the volume of shipments. Using the methodology presented in the report, current or projected production data can be incorporated as they become available.

The food and fiber system is composed of many activities and industries. Transportation services are necessary to get farm inputs from manufacturing plants to farms, raw agricultural products to processors or consumers, and manufactured food products from processing plants to the retail sector. Estimated fuel requirements for transportation across the food system in 1977 were 2,892 million gallons of diesel fuel and 411 million gallons of gasoline (table 1). This compares with 2,722 million gallons of diesel fuel and 3,549 million gallons of gasoline used in farm production.

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Table 1--Estimated transportation fuel requirements in the food and fiber system, 1977

Item	Ton-miles	Diesel fuel	Gasoline
	Millions	---Million gallons---	
Farm inputs	82,539	505	114
Agricultural commodities	141,098	1,119	297
Manufactured food products	116,077	1,268	--
Total	339,714	2,892	411

-- = Not applicable.

Of farm inputs, the distribution of fertilizer products required the most petroleum fuel. Of agricultural commodities, grain shipments accounted for about 46 percent of total fuel requirements, and fresh fruit and vegetable shipments accounted for 37 percent. Truck shipments made up 41 percent of total ton-miles in the food and fiber system and required about 2,529 million gallons of petroleum fuels, or 77 percent of the total. Rail movements required 665 million gallons of fuel, or 20 percent of the total. Barge shipments made up virtually all of the remainder, and accounted for substantial proportions of the ton-miles of fertilizer and grain shipments.

Transportation fuel requirements for different products can vary by region, season, and year. These variations can be large on the local level because of regional specialization in production and because of such variables as yield and market considerations. Fruits and vegetables going to processors are the most seasonal of the major commodities, while animal products and manufactured food products exhibit no significant seasonal shipping patterns. Annual variations in transportation requirements result primarily from changes in production volumes. Variability in grain, soybean, fruit, and vegetable production has the greatest impact on fuel requirements.

METHODOLOGY

The basic methodology in this report uses tonnage data, estimates of average mileages, and fuel efficiency data to estimate fuel requirements. It represents the most efficient way of analyzing fuel use for transportation across the food and fiber system. In many cases, significant improvements in the data can only be made through extensive shipper surveys. A commodity-by-commodity approach, involving a series of separate, detailed studies, would increase the reliability of fuel estimates. However, extensive surveys and studies of commodity movements would have exceeded the time and resources available because of the large number of commodities and the scope of the subject matter investigated here.

Annual fuel requirements are determined by first estimating ton-miles (the product of total tonnage and weighted average mileage) a product is shipped. The ton-miles are then multiplied by fuel efficiency data, measured in British thermal unit (Btu) requirements per ton-mile, to obtain fuel requirements.

Most estimates are based on U.S. Department of Agriculture (USDA) production and processing volume data for 1977. Earlier data are used where no 1977 data exist. Secondary data are also used for ton-mile estimates for farm inputs. Ton-miles for manufactured food products are estimated from data in the 1972 Census of Transportation, the latest available source of such information (17). 1/

Vehicle fuel consumption data are from the U.S. Department of Transportation. Fuel requirements per ton-mile for trucks are constructed to include empty return trips (see appendix). For cotton, fresh fruits and vegetables, grains, and manufactured foods, where long distance truck movements are common, the hauling of other commodities on the return trip (backhauling) often occurs. To the extent that backhauling exists, fuel requirements will be overstated. The backhaul issue is treated in a later section.

Fuel coefficients for trucks are reported on the basis of vehicle size. The fuel coefficients applied correspond to the type of truck which is most prevalent in the movement of a particular commodity. Fuel efficiency estimates for rail and barge shipments are based on averages of loaded movements of all agricultural commodities and empty returns. No gasoline is used for these transport modes.

The error associated with Btu coefficients is directly reflected in calculated fuel requirements. If a ton-mile figure is accurate, the percentage error in the fuel estimate will be no smaller than the percentage error in the Btu coefficient. There was often little available information with which to select Btu coefficients, so fuel estimates should be interpreted with caution and should be accorded less confidence than ton-mile estimates.

It is assumed that diesel and gasoline use is related to truck size where information on fuel type use is not available. Trucks smaller than 50,000 pounds gross vehicle weight are assumed to use gasoline. Most of the gasoline use is in the farm production sector. Generally, information on the proportions of gasoline diesel fuel use on a commodity-by-commodity basis is limited.

ANNUAL TRANSPORTATION FUEL REQUIREMENTS

Over 3.3 billion gallons of fuel were used to transport products in the food and fiber system in 1977: 619 million gallons for farm inputs, 1,416 million gallons for agricultural commodities, and 1,268 million gallons for manufactured food products.

Agricultural Inputs

Data indicate that it takes 114 million gallons of gasoline and 505 million gallons of diesel fuel annually to transport the seven major farm inputs: fertilizers, farm machinery, pesticides, formula feeds, petroleum fuels, feeder livestock, and crop seeds (table 2). Other miscellaneous inputs, such as contract combining and

1/ Underscored numbers in parentheses refer to references listed at the end of this report.

Table 2—Estimated fuel requirements to transport selected farm inputs, 1977

Item	Ton-miles	Btu's	Diesel fuel	Gasoline
	Millions	Billions	---Million gallons---	
Fertilizers	43,543	27,751	190	5
Farm machinery	1,905	4,372	27	0
Pesticides	506	490	4	0
Formula feeds	18,506	26,058	164	30
Petroleum fuels	13,733	35,020	59	59
Feeder livestock	3,281	8,365	42	20
Crop seeds	1,065	2,716	19	0
Total	82,539	104,722	505	114

aerial applications of pesticides, are not included because of data limitations and the small magnitude of transportation fuel requirements. The distribution of fertilizers, formula feeds, and petroleum products accounts for about 80 percent of the fuel consumed.

Fertilizers

Transportation of 114 million tons of fertilizers in 1977 involved almost 44 billion ton-miles and required over 190 million gallons of diesel fuel (table 3). Truck movements accounted for only 14 percent of total ton-miles, but they accounted for 48 percent of fuel requirements for fertilizer transportation. After distribution from plants to terminal storage points by barge, rail, and pipeline, all fertilizers are eventually trucked an average of 100 miles from terminals to retail outlets, and then 5 miles from retail outlets to farms. All fuel associated with the movement from terminals to retailers is assumed to be diesel fuel, while all fuel associated with deliveries to farmers is assumed to be gasoline.

Farm Machinery

The 1972 Census of Transportation reports ton-mile figures for selected Standard Industrial Code (SIC) industries. Ton-miles for farm machinery and equipment (SIC 352) in 1972 totaled 1,905 million, with rail movements accounting for 37.1 percent of total ton-miles and trucking for 61.3 percent (18). The number of machines going to farmers in 1977 was only slightly lower than in 1972, so it is assumed that total energy requirements for the distribution of farm machinery and equipment in 1977 were equal to those calculated for 1972, or approximately 26.5 million gallons of diesel fuel (table 3).

Pesticides

The distribution of all pesticide products in 1977 required 3.5 million gallons of diesel fuel (table 3). Approximately 500,000 tons of active chemicals are used in pesticide production annually. These materials are shipped an average of 750 miles, mostly by rail, to formulating plants. The active materials are converted into a usable form at formulating plants by the addition of inactive carrier materials, and

Table 3--Estimated fuel requirements to transport fertilizers, farm machinery, and pesticides, 1977

Commodity and mode	Tons	Average mileage	Ton-miles	Btu's per ton-mile	Total Btu's	Diesel fuel	Gasoline
	Millions	Number	Millions	Number	Billions	Million gallons	
Fertilizer:							
Barge	29.8	800	23,816	290	6,907	49.3	--
Pipeline	1.3	600	798	379	302	2.2	--
Rail	25.9	500	12,945	562	7,275	52.0	--
Truck	57.0	105	5,984	2,127	13,267	86.6	4.9
Total	114.0	--	43,543	--	27,751	190.1	4.9
Farm machinery:							
Rail	.8	880	707	1,621	1,146	8.2	--
Truck	2.4	500	1,198	2,134	2,557	18.3	--
Total	3.2	--	1,905	--	3,703	26.5	--
Pesticides:							
Rail	.5	750	375	562	211	1.5	--
Truck	.9	150	131	2,127	279	2.0	--
Total	1.4	--	506	--	490	3.5	--

-- = Not available or not applicable.

Sources: (1) for fertilizer modal breakdown, and average mileage, (10) for 1977 fertilizer tonnage estimates, and (6) for all Btu coefficients.

product weight is increased to approximately 900,000 tons. Generally, pesticides are then transported by truck to distributors and on to farmers for a total average distance of approximately 150 miles.

In addition to these tonnages, there are approximately 125,000 tons of petroleum and sulfur pesticides which do not go to a formulator, but can be assumed to follow a distribution pattern similar to that of other pesticides.

Formula Feeds

Some 148 million tons of formula feeds are moved 18.5 million ton-miles, using nearly 200 million gallons of petroleum fuel. Data on transportation fuel requirements for finished formula feeds are developed from 1969 mileage estimates and 1977 tonnage figures (23, 24). It is assumed that mileages have not changed substantially in the intervening years (table 4). Truck movements accounted for 61 percent of total ton-miles in 1975 and rail shipments accounted for 39 percent.

Petroleum Fuels

Available data on the transportation requirements of bulk petroleum products from distributors to farms in Midwestern States indicate that 19 gallons of petroleum fuel are delivered for each petroleum delivery truck-mile traveled (7). At 5

Agricultural Commodities

The transportation of commodities from farms to processors involves around 141 billion ton-miles of shipments and consumes 1.4 billion gallons of petroleum fuels (table 7). Transportation of grains and soybeans accounts for about two-thirds of total ton-miles for agricultural commodities and consumes around 60 percent of total gasoline requirements. The transportation of grains, soybeans, fruits, and vegetables together accounts for more than 90 percent of total ton-miles and nearly 85 percent of total diesel fuel requirements.

Table 7--Estimated fuel requirements to transport agricultural commodities to processors, 1977

Item	Ton-miles	Diesel fuel	Gasoline
	Millions	---Million gallons---	
Grains and soybeans	94,533	451	203
Fruits and vegetables	33,721	503	22
Livestock	3,706	54	14
Milk	3,172	38	23
Sugar	1,846	15	11
Poultry and eggs	1,117	26	16
Peanuts	79	1	1
Cotton	2,716	27	6
Tobacco	208	4	1
Total	141,098	1,119	297

Grains and Soybeans

Transportation of grains and soybeans involves approximately 94.5 billion ton-miles and requires about 650 million gallons of petroleum fuels (table 8). To estimate ton-miles, grain and soybean transportation was divided into two components: from farm to first elevator, and from first elevator to processor or export port.

This approach represents a simplification of actual grain transport practices in that movements generally involve a second or third elevator prior to shipment to final user. However, the breakdown of grain shipments into two distinct types of movements facilitates the generation of total ton-mile estimates without sacrificing a great deal of accuracy. Mileage estimates for shipments from first elevator to grain consumers are large enough to outweigh additional movements associated with intermediate shipping and handling.

Soybean exports are included with grain exports because of similarities in shipping patterns. Exports involve the greatest number of ton-miles, due in large part to the greater distances between supply and assembly points (table 8).

Table 8--Estimated fuel requirements to transport grains and soybeans, 1977

Grain Movement	Ton-miles	Btu's per ton-mile 1/	Total Btu's	Diesel fuel	Gasoline
	Millions	Number	Billions	---Million gallons---	
To first elevator:					
Truck	6,806	4,671	31,790	45	203
To processor:					
Food grains--					
Truck	3,045	2,550	7,765	55	0
Rail	12,180	697	8,489	61	0
Feed grains—					
Truck	2,304	2,550	5,876	42	0
Rail	9,217	697	6,424	46	0
Soybeans—					
Truck	1,333	2,550	3,399	24	0
Rail	2,204	697	1,536	11	0
Barge	651	172	111	1	0
To export:					
Truck	1,136	2,550	2,897	21	0
Rail	20,445	697	14,250	102	0
Barge	35,212	172	6,056	43	0
Total	94,533	—	88,593	451	203

-- = Not applicable.

1/ Assumes small trucks (7.3-ton capacity) are used most often for farm to first elevator movements and larger trucks (22.1-ton capacity) are used for all other movements.

Movements from farms to first elevators.--The distance between farms and first elevators is estimated to average 30 miles for all grains and 15 miles for soybeans. It is estimated that 80 percent of the fuel consumed in hauling grains to the first elevator is gasoline and all fuel consumed in transportation beyond the first elevator is diesel.

Food grains.--Volumes of corn, wheat, barley, and oats shipped to food processors are developed from Census data. The food processing industries considered were malt beverages (SIC 2082), malt (SIC 2083), distilled liquor (except brandy) (SIC 2085), flour and other grain mill products (SIC 2041), cereal breakfast foods (SIC 2043), and wet corn milling (SIC 2046). Mileages are estimated from data on plant density and grain production density. For example, most wet-corn milling plants (SIC 2046) are located in Wisconsin, Minnesota, and Illinois, close to corn production areas. At the other extreme, malt beverage plants (SIC 2082) are located near population centers.

Wheat shipped to plants in the flour and other grain mill products industry (SIC 2041) was responsible for 58 percent of the total ton-miles for food grains from primary elevators (appen. table 2). It is assumed that rail shipments account for 80

percent of total ton-miles and truck movements account for the remainder. Some amount of food grains move by barge, but this is assumed to be insignificant in comparison to rail and truck shipments.

Feed grains.--Ton-miles of feed grain shipments to processors in 1977 totaled 11,522 million (appen. table 2). Corn movements constitute the bulk of feed grain shipments to processors. A substantial proportion of the grain hauled less than 400 miles moves by truck. It is assumed that 80 percent of the total ton-miles from the first elevator to the feed manufacturer is by rail and 20 percent by truck.

Soybeans.--Soybeans hauled to crushing plants are converted into soybean meal (used as a protein supplement in livestock feeds) and oil (primarily used in the food processing industry). About 70 percent of soybeans going to crushers move by truck. Transportation of soybeans to crushing plants involves approximately (appen. table 2). Soybean meal and oil transportation requirements are considered in the manufactured food products section.

Exports.--Barge shipments account for the largest share of total ton-miles for exports (table 8). Some 80 to 90 percent of exports from the New Orleans and Mobile areas and about 30 percent from the Columbia River (Portland) area are assembled by river barge. Rail accounts for most of the remainder, while some trucking to export ports occurs for lesser distances. An estimated 62 percent of total ton-miles are by water, 36 percent by rail, and 2 percent by truck.

Fruits and Vegetables

Fruits and vegetables are moved 33.7 million ton-miles, using 525 million gallons of fuel. Transportation of fruits and vegetables is divided into two parts in order to develop the ton-mile estimates and fuel requirements: shipments of fresh produce to terminal markets, and shipments to processing plants.

Fresh fruits and vegetables.--Fresh produce is hauled from fields to concentration or shipping points where it is packaged, precooled, and loaded into trucks or rail cars for shipment to a terminal market. Mileages between growing areas and shipping points vary by commodity and by region; however, it is assumed that the average distance is 8 miles. Shipments of 20 to 30 miles do occur, but shipping points are generally centrally located in growing areas and draw from a much smaller radius. Production for the fresh market is concentrated in certain regions, particularly California and Florida, so mileages from growing areas to major consuming regions tend to be substantial.

Transportation requirements for fresh fruits and vegetables from shipping points to markets, as shown in table 9, are developed from (12) and appendix table 5. Operations of small local growers and distributors are not included in this analysis. However, distances are generally much less for local or truck-farm movements than for the intercity commodity flows, so total ton-miles would be small in comparison to the figures reported here. Presently, there are no estimates for fuel use at this level. It is assumed that the bulk of fuel used for local truck farm and roadside operations is gasoline.

Nearly all of the gasoline consumed to transport fresh fruits and vegetables is associated with the hauling of produce from fields to shipping points. It is assumed that all fuel consumed in this movement is gasoline because of the relatively small distances involved. All fuel consumed in shipping fresh produce to terminal markets is assumed to be diesel.

Table 9--Estimated fuel requirements to transport fresh and processed fruits and vegetables, 1977

Item	Ton-miles	Btu's ton-mile	Total Btu's	Diesel	Gasoline
	Millions	Number	Billions	---Million gallons---	
Fresh fruits and vegetables:					
Field to shipping point	242	4,671	1,132	0	9
Shipping point to market--					
Truck	21,828	2,608	56,928	407	0
Rail	8,630	755	6,516	47	--
Total	30,458	--	63,444	454	9
Processed:					
Fruits	1,256	--	3,338	23	2
Vegetables	1,765	--	5,109	26	11
Total	3,021	--	8,447	49	13
Total fresh and processed	33,721	--	71,891	503	22

-- = Not applicable (see appendix).

Processed fruits and vegetables.--Processing plants are generally located in or adjacent to growing areas. Hauling distances are relatively short and produce is shipped directly from growing areas to plants. Trucks are used almost exclusively for these shipments, although rail is often used for some potato processors (particularly potato chip manufacturers). Refrigeration is not necessary for most movements of fruits and vegetables to processors because transit times are limited.

Estimates of ton-miles for processed fruits and vegetables (table 9) were developed from average mileage figures provided by growers and production data (appendix tables 6 and 7). Gasoline use in hauling fruits and vegetables to processors is estimated at about 25 percent of total fuel consumption. Diesel is used almost exclusively to transport tomatoes in California, which comprises more than 25 percent of total ton-miles. However, around 25 percent of fuels consumed to transport Florida oranges and grapefruit is gasoline. It is assumed that most of the smaller volume movements rely on gasoline.

Livestock

Transportation of livestock from feedlots to slaughter involves approximately 3.7 million ton-miles and requires around 68 million gallons of petroleum fuels (table 10). The average distance for all livestock movements is estimated at 125 miles. Cattle movements account for 63 percent of total ton-miles. Most livestock is hauled from feedlots in large trucks, and 80 percent of the fuel consumption is diesel.

Milk

Raw milk is transported around 3 billion ton-miles, requiring approximately 38 million gallons of diesel fuel and 23 million gallons of gasoline (table 11).

Raw milk moving more than 50 miles is normally handled at intermediate receiving points, which consist of either receiving stations where the milk is unloaded into tanks or reload stations where the milk is pumped from smaller vehicles directly into larger tank trucks. Milk moving less than 50 miles is usually shipped directly to plants.

Most raw milk shipped to bulk fluid plants is hauled far enough to require intermediate handling. For the most part, raw milk shipped to manufacturing plants is hauled less than 50 miles and is, therefore, shipped directly to plants. Mileages

Table 10--Estimated fuel requirements to transport livestock to slaughter, 1977

Item	Tons shipped	Ton-miles	Btu's per ton-mile	Total Btu's	Diesel fuel	Gasoline
	Thousands	Millions	Number	Billions	--Million gallons--	
Cattle	18,594	2,323	2,550	5,923	34	9
Hogs	10,128	1,266	2,550	3,228	18	5
Calves	392	49	2,550	125	1	0
Sheep and lambs	540	68	2,550	173	1	0
Total	29,654	3,706		9,449	54	14

Table 11--Estimated fuel requirements to transport raw milk, 1977

Item	Ton-miles	Btu's per ton-mile	Total Btu's	Diesel fuel	Gasoline
	Millions	Number	Billions	---Million gallons---	
Raw milk to bulk fluid plants:	2,386	2,550	6,084	35	10
Raw milk to manufacturers:	786	2,550	2,005	3	13
Total	3,172	—	8,089	38	23

-- = Not applicable.

to bulk fluid and manufacturing plants vary by region (appen. table 8). No refrigeration equipment is used in shipping raw milk; milk is precooled at farms, and truck tanks are well insulated.

Truck size generally ranges from 10- to 20-ton capacity for movements of 50 miles or less. For shipments from collection points, trucks of 20- to 26-ton capacity are used. About 20 percent of fuel consumption for shipments to bulk fluid plants and 80 percent for shipments to manufacturers is gasoline.

Sugar Crops

The transportation of sugar beets, sugarcane, sugar, and byproducts requires approximately 41 million gallons of petroleum fuels annually (table 12). U.S. sugar production in 1977 totaled 6.26 million tons (9). Domestic sugar production averages averages around 50 percent of domestic consumption, and is about 60 percent beet and 40 percent cane sugars. Approximately two-thirds of the cane sugar refined is imported as raw sugar. Some 70 percent of the sugar consumed in the United States is used in the food industry, with the beverage industry being the largest industrial user.

Sugar beet production is concentrated in several areas in the West and Midwest. Sugar beets are hauled from growing areas by truck and rail to processing plants where the beet sugar is refined. Beet pulp is the major byproduct of beet milling and is used as a livestock feed ingredient. It is estimated that 30 percent of fuel consumption is diesel.

Table 12--Estimated fuel requirements to transport sugar crops, 1977

Item	Ton-miles 1/	Btu's per ton-mile	Total Btu's	Diesel fuel	Gasoline
	Millions	Number	Billions	---Million gallons---	
Sugar beets:					
Rail	1,046	697	729	5	2/
Truck	392	4,671	1,831	4	10
Beet pulp:					
Truck	137	2,550	349	3	2/
Sugarcane:					
Rail	38	697	26	2/	2/
Truck	233	2,550	594	3	1
Total	1,846	—	3,529	15	11

-- = Not applicable.

1/ From appen. tables 9 and 10.
2/ Less than 0.5 percent.

Table 14--Estimated fuel requirements to transport peanuts, tobacco, and cotton, 1977

Item	Tons	Average mileage	Ton-miles	Btu's per ton-mile	Total Btu's	Diesel fuel	Gasoline
	Thousands	Number	Millions	Number	Billions	---Million gallons---	
Peanuts:							
Farm to warehouse	925	10	9	4,671	43	—	0.4
Warehouse to sheller	925	45	42	2,550	106	0.8	—
Farm to sheller	925	30	28	4,671	130	.4	1.0
Total/average	1,850	—	79	—	279	1.2	1.4
Cotton:							
Seed cotton to gin	11,759	8	94	4,671	439	—	3.5
Cottonseed	5,018	50	251	2,550	640	4.6	
Debris	1,142	50	57	4,671	267	—	2.1
Lint							
Rail	--		1,481	697	1,032	7.4	—
Truck	—	—	833	2,550	2,124	15.7	--
Total	—	--	2,716	—	4,502	27.2	5.6
Tobacco:							
To auction	956	18	17	4,671	79	—	.6
To processing	956	200	191	2,550	487	3.5	--
Total/average	956	—	208	—	566	3.5	.6

— = Not applicable.

Table 15--Estimated fuel requirements to transport manufactured food products, 1977

Movement of products	Tons	Average mileage	Ton-miles	Btu's	Diesel fuel
	Millions	Miles	Millions	Billions	Million gallons
To warehouse 1/	277	765	101,227	139,774	998
To supermarket	297	50	14,850	37,868	270
Total	—	--	116,077	177,642	1,268

-- = Not applicable.

1/ See appen. table 13 for a further breakdown.

barges carrying fertilizer up the Mississippi can be more than 50 percent greater than for grain shipments going down the river.

Total fuel requirements are to a large degree dependent upon the transport system used as well as the number of tons carried and total miles traveled. Truck and rail ton-miles are approximately the same for the entire food and fiber system, but truck fuel use is nearly four times that of rail (table 16).

Table 16--Ton-miles and fuel requirements by mode, 1977

Item/mode	Ton-miles	Diesel fuel	Gasoline
	Millions	---Million gallons---	
Farm inputs:			
Truck	32,868	336	115
Rail	25,057	117	--
Barge	23,816	49	--
Pipeline	798	2	--
Agricultural commodities:			
Truck	49,994	796	297
Rail	55,241	279	--
Barge	35,863	44	--
Manufactured food products:			
Truck	56,025	986	--
Rail	53,234	269	--
Barge	6,818	13	--
Total food and fiber system:			
Truck	138,887	2,118	411
Rail	133,532	665	--
Barge	66,497	106	--
Pipeline	798	2	--
Total	339,714	2,891	411

-- = Not applicable.

The length of shipment and the per-ton commodity value determine to a large extent the transport mode that is used. Rail and barge shipments tend to involve longer distances and commodities that have less value per ton of product.

Trains carry mainly nonperishable commodities, such as grains, soybeans, cotton, and various manufactured food products. However, refrigerated rail shipments of fresh fruits and vegetables are substantial. Nearly all barge traffic is grains, soybeans, and fertilizers.

Trucks are the predominant mode for transporting perishable commodities and for moving products over relatively short distances. Trucking operations are more flexible than barge and rail in terms of scheduling and are accessible to a far greater

number of users. Truck shipments are faster than rail or barge, hence the greater reliance on trucking for perishable commodity shipments.

Given the differences in fuel efficiencies, fuel requirements could be reduced if more products were shipped by barge or rail and less by truck. It is likely, however, that substantial shifts in modal transport will not occur in the next 10 to 20 years because of the existing transport infrastructure. Further development of waterway systems is not likely to increase barge traffic greatly because of the limited accessibility of waterways, located primarily in the Mississippi River system and the Southeast, to other producing and consuming regions. The existing rail system would require massive amounts of investment to cut into the trucking market. The trucking industry is better able to serve many producers and haul most perishable commodities because of scheduling and origin-destination flexibility and speed of transit.

SEASONAL FUEL USE

Available data indicate that food and fiber system transportation requirements, on the aggregate level, are relatively stable throughout the year. However, a high degree of seasonality in shipment patterns may exist on the commodity or regional level. Only general observations can be made regarding seasonality of fuel requirements because of data limitations associated with commodity, regional, and annual variations in patterns of shipments.

Transportation requirements are more seasonal for farm inputs than for either agricultural commodities or manufactured food products. Manufactured food products are the least seasonal in terms of shipments from producers to consumers because of the perishability of many food products and the constancy of consumer demand. In this analysis, shipments of manufactured food products are assumed to be constant throughout the year.

Estimates of quarterly petroleum fuel consumption for the transportation of farm inputs, agricultural commodities, and manufactured food products are shown below:

Item	Quarter			
	I	II	III	IV
	Million gallons			
Farm inputs	150	188	131	146
Agricultural commodities	335	338	404	336
Manufactured food products	317	317	317	317

Agricultural Inputs

Transportation requirements for fertilizers, crop seeds, and pesticides are highest in the spring and summer, the periods of heaviest use. Livestock feed, machinery, and feeder livestock exhibit less seasonality in transportation requirements (table 17).

Agricultural Commodities

The transportation of agricultural commodities is not highly seasonal in the aggregate (table 18). Grain, soybean, fruit, and vegetable transportation fuel requirements together represent about 90 percent of total ton-miles for all agricultural commodities. Off-farm transportation requirements for grains and soybeans may be higher in the fall, while nearly all fruit and vegetable transportation to processors occurs in the summer months. However, fuel requirements to transport grains and soybeans from farms to first elevators are less than one-third of the total for all grain and soybean movements (table 8). Likewise, the relative fuel requirements to transport fruits and vegetables to processors are just over 10 percent of all fruit and vegetable movements (table 9).

Livestock, poultry, dairy, and baled cotton shipments are relatively constant throughout the year. Movements of sugar crops, peanuts, seed cotton, and tobacco are seasonal, but the associated fuel requirements are small.

Grains and Soybeans

The seasonality associated with off-farm movements of grains and soybeans depends to a large degree on the relationship between crop size and onfarm storage capacity. There was enough capacity in onfarm storage in 1978, for example, to absorb production volumes and smooth out shipment volumes. This was not the case in previous years, and there were substantial seasonal off-farm movements. It should be noted that seasonal demand for transportation services generally occurs from July through November, but can vary by crop and region.

Table 17--Quarterly percentages of estimated fuel requirements to transport major farm inputs, 1977

Item	Quarter			
	I	II	III	IV
	Percent			
Fertilizers	30	40	15	15
Farm machinery	25	25	25	25
Pesticides	20	50	20	10
Formula feeds	25	25	25	25
Petroleum fuels	15	25	30	30
Feeder livestock	20	20	20	40
Crop seeds	20	50	20	10

Table 18--Quarterly percentages of estimated fuel requirements to transport agricultural commodities, 1977

Item	Quarter			
	I	II	III	IV
	Percent			
Grains and soybeans	25	25	25	25
Fresh fruits and vegetables	25	25	25	25
Processed fruits and vegetables	0	0	100	0
Livestock	25	25	25	25
Milk	25	25	25	25
Sugar	20	20	30	20
Poultry and eggs	25	25	25	25
Cotton	25	25	25	25
Peanuts	20	0	50	30
Tobacco	0	50	50	0

Shipments from subterminal and terminal elevators, which account for the bulk of ton-miles, are relatively constant throughout the year, although barge movements are somewhat restricted by freezing over in the winter and flooding in the spring. Grain and soybean processing and export are also fairly constant throughout the year (table 19).

Fruits and Vegetables

The transportation of fresh fruits and vegetables is somewhat seasonal, with receipts of fresh produce at terminal markets higher in late spring and summer (table 20). In the winter and spring, however, shipments from Florida, Texas, Arizona, and Mexico increase relative to most other sources. The additional mileages involved during this period tend to offset the higher volumes of produce shipped in the summer months. Thus, total transportation fuel requirements for fresh fruits and vegetables, which may be highly seasonal on the local level, are not highly seasonal on the aggregate level.

Fruit and vegetable processing is highly seasonal, with nearly all transportation fuel consumed from late June through early September.

Other Agricultural Commodities

Livestock slaughter, milk processing, and poultry processing are continuous operations, with transportation requirements varying little throughout the year (table 21). Turkey slaughter exhibits some seasonality, but the associated fluctuations in transportation requirements are small.

Table 19--Monthly percentages of grain and soybean shipments, 1977

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Percent											
Rail shipments of grain	7	7	7	7	10	9	11	7	9	8	10	8
Barge shipments of grain 1/	6	5	8	8	11	9	8	12	8	9	10	7
Wheat flour 2/	8	8	9	8	9	8	8	9	8	9	9	9
Soybean oil 2/	9	8	9	8	9	7	7	8	7	9	9	10
Grain exports 2/	6	7	8	8	10	10	9	10	9	8	8	8

1/ From (21).
2/ From (20).

Table 20--Monthly percentages of fresh fruit and vegetable unloads, by origin, 1977

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Thousands of rail carlot equivalents											
California	13	13	16	16	19	26	27	28	24	20	18	16
Florida	9	5	7	9	16	12	2	—	—	3	8	10
Texas	3	3	3	3	6	8	6	4	2	2	3	3
Arizona	1	1	1	1	1	1	1	—	—	—	1	2
United States	41	35	42	42	54	66	59	61	53	48	49	46
Mexico	4	5	7	8	5	2	—	—	—	—	1	2

-- = Less than 0.5 percent.

Source: (13).

Movements of sugar crops, peanuts, cotton, and tobacco from farms to first processors are seasonal. The total amount of fuel consumed in transporting these commodities, however, is very small in relationship to other agricultural commodities.

ANNUAL VARIABILITY

Annual fuel requirements to transport commodities can fluctuate significantly as a result of changes in production volumes and shipping patterns. Changes in annual production volumes of fertilizers (the major farm input with respect to transportation

Table 21--Monthly processing of livestock, poultry, and milk, 1978

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Percent						
Livestock:												
Cattle	9	8	9	8	9	8	8	8	8	9	8	8
Hogs	8	8	9	8	8	8	7	8	8	9	9	8
Poultry:												
Chickens	7	7	8	7	9	9	8	10	9	10	9	8
Turkeys	7	5	5	4	4	6	9	12	15	17	9	7
Eggs	8	8	8	8	9	8	8	8	8	9	8	9
Dairy:												
Butter	11	10	10	10	10	8	7	6	6	7	7	8
Fluid milk	8	8	9	9	9	9	9	8	8	8	8	8

Source: (20).

requirements) and major agricultural commodities for the last several years are shown in table 22.

The variability of fertilizer, grain, and soybean production has the greatest impact on fuel consumption, because of associated transportation requirements. The use of fertilizers increased by 27 percent from 1970 to 1971, and the production of grains and soybeans increased substantially from 1974 to 1975. It should be noted, however, that changes in production volumes may not necessarily translate into equivalent annual changes in shipment volumes. Storage practices can smooth out annual transportation requirements to the extent that stocks are carried over into the next year.

It is likely that aggregate transport fuel requirements will not vary by more than 5 to 10 percent annually. Although the relative changes in total transport fuel requirements are not large, the amounts of diesel fuel and gasoline involved can be substantial. Furthermore, variations in fuel requirements may be much larger on a product-by-product basis or on the regional level.

REGIONAL FUEL USE

Regional differences in agricultural production and food consumption result in variations in transport fuel requirements. Fuel requirements to transport farm inputs, agricultural commodities, and manufactured foods by census regions are shown in table 23 (see fig. 1 for census regions).

Fertilizer and feed consumption, and grain production in regions 3 and 4 result in relatively larger fuel requirements. Together, regions 3 and 4 account for 44 percent of agricultural commodity shipments and 35 percent of farm input shipments.

Ton-mile shipments for farm inputs and manufactured foods by region are from (19). Regional production data were used to estimate ton-miles for agricultural

Table 22--Production indices for food and fiber system commodities

Item	1970	1971	1972	1973	1974	1975	1976	1977
					1970=100			
Fertilizers 1/	100	127	122	127	110	133	138	140
Grains	100	104	113	137	108	137	114	152
Soybeans	100	106	164	175	150	191	182	--
Grain and soybean exports	100	99	102	103	96	107	116	107
Fruits and vegetables	100	101	110	116	123	129	126	125
Sugar (beet and cane)	100	89	92	91	104	115	112	100
Red meats	100	103	135	127	113	82	104	141
Milk	100	101	103	99	99	99	103	105
Broilers and turkeys	100	102	102	97	97	95	95	95
Eggs	100	101	106	105	106	105	118	121
Peanuts	100	104	101	94	102	99	106	106
Cotton	100	104	101	113	115	123	117	123
Tobacco	100	104	104	109	118	106	123	128

-- = Not available.

1/ Rate of application.

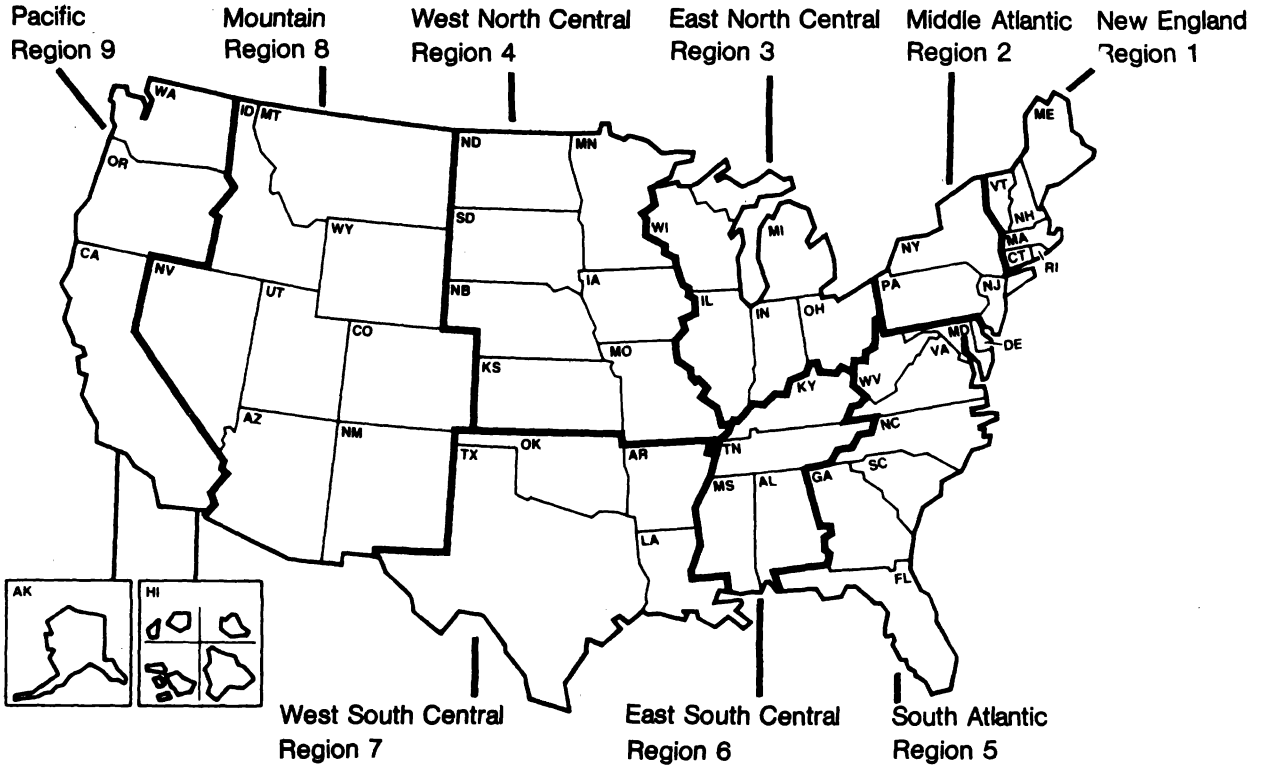
Source: (10).

commodities. It is assumed that all raw products are processed in the region where produced. There undoubtedly are large volumes of commodities moving between regions for processing, but it is likely that movements balance out in the aggregate. The one exception that significantly affects regional fuel requirements is barge and rail shipments of grain from regions 3 and 4 moving through regions 6 and 7 to the Gulf ports. To account for this, ton-miles in regions 6 and 7 were adjusted upward slightly.

There is a lack of data on regional ton-miles for fresh fruit and vegetables, so ton-miles reported by Census for SIC 203--canned and preserved fruits and vegetables--are used to approximate a regional breakdown. This is a reasonable approach,

Figure 1

Census Regions in the United States



since the regional percentages of ton-miles for SIC 203 correspond closely to the regional proportions (by origin) of fresh fruits and vegetables shipped.

Regional fuel requirements for the movement of manufactured food products are based on both the location of food processing plants and population (demand) densities. This accounts for the more even distribution of fuel requirements among regions as opposed to those for farm inputs or agricultural commodities.

It should be acknowledged that the present level of data development and conceptual problems leads to difficulties in estimating regional fuel requirements. Among the most important limitations of these estimates is the arbitrary definition of regions. Fuel consumption in a region is to a large degree dependent on the size of the region and mileages involved. Furthermore, production and consumption densities within regions are not uniform, and the number of potential shipping patterns which involve different regions may be large.

In the absence of detailed product-by-product transportation studies, estimates of regional fuel requirements are likely to be more accurate the higher the level of product aggregation. Therefore, the estimates presented above are useful as an index of regional fuel use rather than as absolute volumes of fuel requirements.

Table 23--Percentages of estimated fuel requirements to transport agricultural products by census region, 1977

Item	Region								
	1	2	3	4	5	6	7	8	9
	Percent								
Farm inputs 1/	0	9	18	17	18	9	16	6	7
Agricultural commodities	2	7	18	25	10	5	11	6	16
Manufactured foods	9	16	17	11	13	7	9	6	12
Total	4	11	17	18	12	7	11	6	14

1/ Includes farm machinery, fertilizers, pesticides, and manufactured feeds.

Table 24--Difference in fuel requirements between loaded and empty return trips, 1977

Item 1/	Percentage of return trips loaded 2/	Petroleum fuel requirements: Including loaded return trips	Excluding loaded return trips	Difference
	Percent	---Million gallons---		
Farm inputs:	—	619	608	11
Farm machinery	31.1	27	24	3
Formula feeds	10.7	194	189	5
Feeder livestock	9.7	62	59	3
Other	—	336	336	0
Agricultural commodities:	—	1,416	1,293	123
Grains and soybeans	10.7	654	648	6
Fresh fruits and vegetables (refrigerated)	36.3	525	411	114
Livestock	9.7	68	65	3
Cotton	22.6	33	31	2
Other	—	169	169	0
Manufactured food products:	—	1,268	1,151	117
Refrigerated	36.3	402	322	80
Unrefrigerated	22.6	866	829	37
Total		3,303	3,052	251

-- = Not available.

1/ Zero backhaul is assumed for items not listed.
2/ From (5).

FUEL CREDIT FOR BACKHAUL OPERATIONS

After truckers make a delivery, they usually try to find a commodity load for the return trip. The reasons for this are that the cost of taking a load on the return trip is not much greater than the cost of returning empty, while the additional revenue can be substantial. This practice, called backhauling, results in greater utilization of truck capacity and increased fuel efficiency. The fuel required to haul a return load is only slightly greater than the fuel required to return empty.

Generally, backhauling is more common in longer distance truck routes, where there is more opportunity and greater incentive to find a return load. A bulk truck moving grain 100 miles in Nebraska, for example, stands less of a chance of finding a backhaul load than a refrigerated van hauling fresh oranges from Florida to Chicago.

Accounting for backhauling practices in the calculation of fuel requirements is not a clear-cut procedure. The most important issue involved is how to charge or attribute the fuel used on the return (loaded) trip; it can be charged either to the product backhauled or the product originally hauled. Some would argue that attributing total fuel use to the primary product shipped would result in a double-counting of fuel requirements, and that only the fuel that is used directly in transporting the primary product is necessary for its distribution. Others would argue that one way or another, trucks must return to pick up another load, and that the fuel required to return empty is necessary for product distribution. Another problem in isolating fuel used in backhauling operations is that many times an agricultural product is the item backhauled, and there are complications in attempting to distinguish necessary versus concomitant fuel use. Table 24 shows percentages of loaded return trips and the differences in calculated fuel requirements if loaded return trips are not charged to the commodity listed.

Movements of fresh fruits and vegetables, manufactured foods, and farm machinery involve the largest percentages of loaded return trips. Refrigerated vans tend to have greater utilization because of higher associated capital costs. Calculating petroleum fuel requirements (diesel and gasoline) on the basis of loaded deliveries and empty return trips only indicates that fuel requirements for movements of fresh fruits and vegetables decrease by 22 percent, while fuel requirements for refrigerated movements of manufactured foods decrease by 20 percent. Estimated fuel requirements for the entire food and fiber system, however, change by only 8 percent, and only 2 percent for all movements other than refrigerated.

In most instances, backhaul practices are limited to long-distance commodity movements. For example, there is no backhaul (except for packing materials) from fresh fruit and vegetable shipping points to growing areas. Likewise, all backhaul associated with manufactured food shipments originates from regional warehouses; there is no backhaul from retail food stores to warehouses.

CONCLUSIONS

The demand for transportation fuel in the food and fiber system is likely to continue to increase in the foreseeable future. Stabilization or reduction in fuel requirements could come about by any combination of the following: reduced tonnages, reduced mileages, improvements in fuel efficiency, or shifts to less energy intensive modes (that is, rail and barge). None of these phenomena are expected to occur to the extent that fuel demand will be substantially reduced.

Production of both agricultural products and manufactured foods will increase to meet growing domestic and foreign demand. Although the trend toward regional specialization of production has slowed, there is no indication that the changing fuel situation will or can affect the spatial relationships between production and consumption. Regional production patterns are determined primarily by regional differences in production costs. With respect to increases in fuel efficiency, further research and development can contribute to a reduction in fuel consumption per ton-mile. However, the replacement of the existing stock of trucks and train engines will take several years. Immediate increases in overall fuel efficiency by means of shifting to rail and barge movements are not imminent because of the existing transportation infrastructure.

Given the number of variables involved, it would be difficult to project absolute amounts of fuel consumption in 1990. However, it would be safe to assume that future levels of agricultural production will have the greatest impact on transportation requirements.

Future fuel allocation policies, whether in the form of rationing, State set-aside programs, or other allocating mechanisms, will likely devote special attention to the vital needs of the food and fiber system. Associated with the development of legislation and the rule-making process will be demands for data on food and fiber system transportation fuel requirements.

Several aspects of the existing state of the art in transportation energy research unfortunately leave significant room for error in estimating fuel requirements. Specifically, the ton-mile energy coefficient is critical in calculating physical quantities of fuel. Errors inherent in fuel estimates are at least as large as potential errors in fuel efficiency coefficients. More research is needed to validate the applicability of these coefficients to actual commodity movements.

Additional research is needed to more accurately estimate diesel-gasoline breakdowns. There are virtually no data available to provide accurate descriptions of the size and fuel consumption characteristics of vehicles used to transport many commodities. The backhaul issue is another area where refinements would be useful. It is difficult to maintain that fuel used in carrying a nonagricultural or food-related commodity is necessary for transporting an agricultural commodity, especially when the latter is the item backhauled.

This report develops first approximations of fuel requirements and identifies those areas where further research would be most valuable. Transportation energy research is a relatively new field. The prospects of fuel shortages for the next several years will require a larger commitment of resources for research, and offer a wide range of research opportunities.

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Fuel Coefficients

A gallon of diesel fuel is assumed to be equivalent to 140,000 Btu's. Gasoline is assumed to have an energy value of 125,000 Btu's.

The Btu coefficient for unrefrigerated rail movements, 697 Btu's per ton-mile, represents an average for all agricultural commodities, with grains accounting for the bulk of shipments. This figure takes into account empty car mileage. A coefficient of 755 Btu's per ton-mile is used for refrigerated rail movements.

The Btu coefficient for barges, 172 Btu's per ton-mile, represents an average for agricultural commodities (including empty trips) on the Mississippi River system. The coefficient for bulk freighter movements of raw cane sugar is 442 Btu's per ton-mile.

Two types of trucks are considered. A truck size of 70,000 pounds gross vehicle weight (GVW) (22.1-ton capacity) using diesel is assumed to be representative of all large trucks. A truck size of 24,000 pounds GVW (7.3-ton capacity) using gasoline is assumed to be representative of all smaller vehicles used. Btu coefficients shown in appen. table 1 are derived by dividing total gallons used for both empty and loaded trips by ton-miles transported.

Appendix table 1--Btu coefficients for trucks, 1977

Representative truck type	Gallons/ton-mile (loaded)	Gallons/ton-mile (empty)	Total	Btu's/ gallon	Btu's/ ton-mile
		Coefficient			
Large truck (22.1-ton capacity):					
Unrefrigerated	0.01089	0.00733	0.0182	140,000	2,550
Refrigerated 1/	.01130	.00733	.0186	140,000	2,608
Small truck (7.3-ton capacity)	.02098	.01683	.0374	125,000	4,671

1/ Assuming 0.55 gallons of diesel fuel per hour for refrigeration unit.

Source: (6).

Ton-Miles for Grains and Soybeans

Ton-miles for movements of grains and soybeans from farm to first elevator, of food and feed grains, and of soybeans to crushing plants are developed from production (or consumption) data and estimated mileages (appen. tables 2 and 3). Ton-miles for exports are based on U.S. Department of Agriculture (USDA) export volume data and estimates of weighted average mileages (appen. table 4).

Appendix table 2--Ton-miles for grains and soybeans, excluding exports, 1977

Grain movement	Amount	Average mileage	Ton-miles
	1,000 tons	Number	Millions
To first elevator:			
Barley	7,254	30	218
Corn	112,786	30	3,384
Oats	4,615	30	138
Sorghum	15,715	30	471
Soybeans	51,486	15	772
Wheat	60,783	30	1,823
Total/average	252,639	27	6,806
Food grains:			
Malt beverages--			
Corn	927	800	742
Barley	277	1,000	277
Malt—			
Barley	3,052	600	1,832
Distilled liquor, except brandy--			
Corn	724	300	217
Flour, other grain mill products--			
Corn	2,683	300	805
Wheat	18,916	500	9,458
Oats	92	400	37
Barley	160	200	32
Cereal breakfast foods--			
Corn	3,080	200	616
Wheat	304	600	182
Oats	487	400	195
Barley	33	800	26
Wet corn millers—			
Corn and Sorghum	8,063	100	806
Total/average	38,798	392	15,225
Feed grains:			
Barley	2,441	229	559
Corn	19,787	371	7,341
Oats	1,697	323	548
Sorghum	7,589	392	2,975
Wheat	819	121	99
Total/average	32,333	356	11,522
Soybeans to crushers	23,162	178	4,188

Appendix table 3--Ton-miles for grain exports, 1977

Region and port 1/	Wheat	Oats	Barley	Corn	Sorghum	Soybeans	Total
			Million ton-miles				
Great Lakes: 2/							
Chicago	3/	3/	3/	269	3/	84	355
Duluth-Superior	534	26	206	3/	3/	3/	766
Toledo	38	3/	3/	476	3/	282	796
Saginaw	3/	3/	3/	3/	3/	3/	3/
Total	572	26	206	745	3/	366	1,917
Atlantic:							
North	168	3/	3/	909	3/	198	1,275
South	221	3/	3/	4,605	3/	875	5,701
Total	389	3/	3/	5,514	3/	1,073	6,976
Gulf:							
Mississippi River	3,888	3/	3/	21,302	95	8,832	34,117
East Gulf	78	3/	3/	106	3/	408	592
North Texas Gulf	3,618	3/	3/	1,674	2,134	527	7,953
South Texas Gulf	585	3/	3/	3/	1,656	3/	2,241
Total	8,169	3/	3/	23,082	3,790	9,767	44,903
Pacific:							
Columbia River	1,590	3/	205	3/	3/	3/	1,840
Puget Sound	360	3/	3/	3/	3/	3/	360
California	390	3/	34	470	3/	3/	894
Total	2,340	3/	284	470	3/	3/	3,094
Total	11,470	26	490	29,813	3,885	11,206	56,890

1/ Ports included in the general areas.
2/ Includes waterway shipments to Canada.
3/ Less than 10 million ton-miles.

Ton-Miles for Fruits and Vegetables

Transportation requirements for fresh fruits and vegetables from shipping points to markets are developed from USDA volumes of shipments data (12), and highway mileages between selected origins and destinations. Destinations are wholesale metropolitan markets, and origins are major shipping points. Fourteen of the 41 city destinations reported on in the unload data are used in this analysis. These were distributed among four regions: West, Midwest, South, and East. The data indicate that shipping point origins are similar for all cities within a given region. For example, the Boston, New York, and Baltimore-Washington markets seem to draw from similar origins. For this reason, a limited number of specified origins are considered for each regional group of destination points.

The composition of transport arrays is as follows: 4 cities and 8 origins in the West; 4 cities and 14 origins in the Midwest; 3 cities and 11 origins in the South; and 3 cities and 14 origins in the East. Origins were selected so as to

Appendix table 4--Grain exports and estimated mileages, by region and port, 1977

Region and port 1/	Wheat	Oats	Barley	Corn	Sorghum	Soybeans	Total
				1,000 tons			
Export volumes:							
Lake States--2/							
Chicago	3/	3/	3/	1,355	3/	420	1,775
Duluth-Superior	2,670	128	1,032	168	3/	3/	3,998
Toledo	480	3/	3/	2,380	3/	1,410	4,270
Atlantic--							
North	480	3/	--	1,652	3/	336	2,468
South	630	3/	3/	8,372	3/	1,590	10,592
Gulf--							
Mississippi River	4,860	3/	3/	26,628	135	11,040	42,663
East Gulf	390	3/	3/	532	3/	2,040	2,962
North Texas Gulf	8,040	3/	3/	2,576	3,556	810	14,982
South Texas Gulf	900	3/	3/		2,548	3/	3,448
Pacific--							
Columbia River	6,360	3/	384	3/	3/	3/	6,744
Puget Sound	1,440	3/	3/	3/	3/	3/	1,440
California	390	3/	168	413	3/	3/	971
Total	26,640	128	1,584	44,076	6,239	17,646	96,313
				Miles			
Mileage:							
Lake States--2/							
Chicago	--	--	--	200	--	200	--
Duluth-Superior	200	200	200	--	--	--	--
Toledo	200	--	--	200	--	200	--
Atlantic--							
North	350	--	--	550	--	550	--
South	350	--	--	550	--	550	--
Gulf--							
Mississippi River	800	--	--	800	--	800	--
East Gulf	200	--	--	200	--	200	--
North Texas Gulf	450	--	--	650	650	650	--
South Texas Gulf	650	--	--	--	650	--	--
Pacific--							
Columbia River	250	--	650	--	--	--	--
Puget Sound	250	--	--	--	--	--	--
California	1,000	--	200	1,200	--	--	--

-- = Not applicable.

1/ Ports included in the general areas.
2/ Includes waterway shipments to Canada.
3/ Less than 50,000 tons.

Source: (14) for tonnages.

maximize the proportion of unloads accounted for and minimize the number of calculations. Thus, the 14 origins chosen for the Midwest account for 85 percent of unloads in St. Louis. The same criterion is used in the selection of destinations.

Unloads in 41 cities account for around 60 percent of total commercial unloads in the United States. Total ton-mile figures for rail and truck data from the 41 cities, therefore, are multiplied by 1.67 to approximate total U.S. ton-miles (appen. table 5).

Estimates of ton-miles for processed fruits and vegetables are developed from average mileage figures provided by growers and processors and USDA production data (9). Given the large number of commodities and growing areas, only combinations of commodity growing areas with the largest volumes are investigated. For example, tomato processing makes up 34 percent of all vegetable processing, and oranges account for 54 percent of fruit processing (appen. tables 6 and 7). Average mileages

Appendix table 5--Ton-miles for fresh fruits and vegetables, 1976 1/

Region	Ton-miles calculated from sample	Percentage of unloads accounted for	Total ton-miles (41 cities)
	Millions	Percent	Millions
West:			
Rail	17	60	27
Truck	1,588		2,561
Midwest:			
Rail	594	60	990
Truck	1,896		3,160
South:			
Rail	105	33	318
Truck	702		2,127
East:			
Rail	1,365	36	3,792
Truck	1,843		5,119
Total 41 cities:			
Rail	2,081	41	5,127
Truck	6,029	46	12,967
United States			
Rail	—	60	8,545
Truck	—	60	21,612

— = Not applicable.

1/ Total ton-miles reported in text are scaled up by 1 percent to account for increased shipments in 1977. From (12) and (13).

Appendix table 6--Fruit processing, by commodity, 1976 1/

Commodity	Tons processed 2/	Average mileage	Ton-miles 3/	Percentage of total-- U.S. processing	Percentage of total-- Fruit processing
	1,000 tons	Miles	Number	---Percent---	
Oranges:					
Florida	8,969	45	404	75	
California	2,589	125	324	22	
United States	11,998	63	751	100	54
Grapes:					
California--					
Raisins	1,026	30	31	88	
Wine	2,704	75	203		
United States	4,241	62	265	100	19
Grapefruit:					
Florida	2,296	45	103	70	
Texas	471	15	7	14	
United States	3,276	40	131	100	15
Apples:					
New York	289	20	6	21	
Michigan	266	40	10	19	
Washington	146	15	2	11	
United States	1,388	25	35	100	6
Peaches, pears, apricots:					
California	772	10	8	81	
United States	951	10	10	100	4
Total	21,854		1,192	—	98
Other fruits	296	55	16	—	2
Total processed fruits	22,150	55	1,208	—	100

— = Not applicable.

1/ Total ton-miles reported in text are scaled up by 4 percent to account for increased levels of processing in 1977. From (10).

2/ Scaled up by 20 percent for grapes, 15 percent for peaches, pears, apricots, and all other fruits, and 10 percent for citrus fruits and apples to account for packing materials. From (9).

3/ Btu coefficients used to calculate table 9 are as follows: oranges, grapes, grapefruit—2,550; apples, peaches, pears, apricots, and other—4,671.

Appendix table 7--Vegetable processing, by commodity, 1976 1/

Commodity/State	Tons processed 2/	Average mileage	Ton-miles 3/	Percentage of total-- U.S. processing	Percentage of total-- Vegetable processing
	1,000 tons	Miles	Number	---Percent---	
Tomatoes:					
California	5,826	95	533	67	34
United States	7,442	95	710	100	
Sweet corn:					
Wisconsin	626	34	21	24	
Minnesota	578	46	26	23	
United States	2,568		100	100	12
Snap beans:					
Wisconsin	196	40	8	29	
Oregon	156	40	6	23	
United States	680		28	100	3
Cucumbers:					
Michigan	118	40	5	16	
United States	729		30	100	3
Potatoes:					
Idaho	3,742		244	39	
United States	9,481		576	100	43
Total	20,900	69	1,444	--	94
Other vegetables	1,314	69	91	--	6
Total processed vegetables	22,214	69	1,535	--	100

-- = Not applicable.

1/ Total ton-miles reported in text are scaled up by 14 percent to account for increased levels of vegetable processing in 1977. From (10).

2/ Scaled up 10 percent for potatoes and 15 percent for all other vegetables to account for packing materials. From (9).

3/ Btu coefficients used to calculate table 9 are as follows: tomatoes, potatoes--2,550; other vegetables--4,671.

are obtained for major producing States. Production volumes, from (9), are scaled up to account for packing containers, and ton-mile figures are calculated. The residual tonnage for each commodity not accounted for is multiplied by the weighted average mileages in the major producing States. The residual tonnages of all vegetables and fruits unaccounted for are multiplied by the weighted average mileages for all vegetable and all fruit commodities, respectively.

Ton-Miles for Milk

Ton-miles for milk shipments to bulk fluid plants and manufacturing plants are shown in appendix table 8.

Ton-Miles for Sugar Beets and Sugarcane

Mileages from beet and cane growing areas to mills and modal breakdowns are from industry sources and tonnages are from USDA data. Ton-miles of shipments by region for sugar beets and sugarcane are shown in appendix tables 9 and 10, respectively.

Appendix table 8--Ton-miles for raw milk, 1976 1/

Region 2/	Milk to fluid plants: Amount	Average mileage	Ton-miles	Milk to manufacturing plants: Amount	Average mileage	Ton-miles	Total ton-miles
	1,000 tons	Number	Millions	1,000 tons	Number	Millions	
New England	1,291	105	133	746	39	29	162
Mid-Atlantic	6,383	124	789	3,679	27	98	887
South Atlantic	2,113	62	131	524	45	23	154
East North Central	3,488	64	224	2,853	30	86	310
South Central	1,385	68	94	1,058	31	33	127
Lake States	2,235	104	231	11,288	15	169	400
Corn Belt	2,368	67	159	4,515	25	111	270
Southwest	1,768	105	186	918	36	33	219
Mountain	600	53	32	1,100	31	34	66
Pacific	3,263	110	358	3,455	45	154	512
United States	24,891	94	2,339	30,134	26	771	3,110

1/ Total ton-miles reported in text are scaled up by 2 percent to account for increased milk production in 1977. From (10). Columns may not add due to rounding.

2/ States within regions are:

New England: Connecticut, Maine, Vermont, Massachusetts, New Hampshire, and Rhode Island

Mid-Atlantic: Virginia, Delaware, New York, New Jersey, Maryland, and Pennsylvania

South Atlantic: Florida, Georgia, North Carolina, South Carolina, and West Virginia

East North Central: Ohio, Michigan, Indiana, and Kentucky.

South Central: Tennessee, Alabama, Mississippi, Louisianna, and Arkansas

Lake States: Minnesota and Wisconsin

Corn Belt: Iowa, Illinois, Missouri, Kansas, Nebraska, North Dakota, and South Dakota

Southwest: Oklahoma, Texas, New Mexico, Arizona, and Nevada

Mountain: Colorado, Wyoming, Utah, Montana, and Idaho

Pacific: Washington, Oregon, and California.

Appendix table 9--Ton-miles for sugar beets, 1977

Area	Amount 1/	Rail			Truck		
		Percentage by rail	Average mileage	Ton-miles	Percentage by truck	Average mileage	Ton-miles
	1,000 tons	Percent	Number	Millions	Percent	Number	Millions
California, Arizona	5,927	42	329	805	58	30	103
Washington, Oregon, Utah, Idaho, Montana	4,968	42	75	156	58	30	86
Colorado, Nebraska, Kansas, Wyoming	4,108	20	100	82	80	15	49
Minnesota, North Dakota	7,530	0	0	0	100	15	113
Texas, New Mexico	332	15	65	3	85	25	7
Michigan, Ohio	2,253	0	0	0	100	15	34
Total/average	25,118	--	--	1,046	--	--	392

-- = Not applicable.

1/ From (10).

Appendix table 10--Ton-miles for sugarcane, 1977

Region	Amount 1/	Rail			Truck		
		Percentage of total tons	Average mileage	Ton-miles	Percentage of total tons	Average mileage	Ton-miles
	1,000 tons	Percent	Number	Millions	Percent	Number	Millions
Florida	8,372	30	15	38	70	15	88
Hawaii	9,769	0	0	0	100	7	68
Louisiana	7,301	0	0	0	100	8	58
Texas 2/	1,200	0	0	0	100	15	18
Total	27,582	--	--	38	--	--	233

-- Not applicable.

1/ From (10).
2/ No modal breakdown is available. It is assumed that all cane in Texas moves by truck.

Appendix table 11--Movements of cotton between selected origins and destinations

ORIGINS \ DESTINATIONS	Birmingham, Ala.	Atlanta, Ga.	Charlotte, N.C.	Greenville, S.C.	Blackstone, Va.	Worcester, Mass.	Detroit, Mich. (Canada)	Charleston, S.C. (Atlantic ports)	Houston,-Galveston, Tex. (Gulf ports)	Los Angeles, Calif. (Pacific Coast)	New Orleans, La.
						Tons					
Montgomery,	15 1/	20	10	18	1	--	--	--	--	--	--
Ala.	42	35	15	12	--	--	--	--	--	--	--
Augusta,	10	--	5	19	--	1	--	--	--	--	--
Ga.	9	--	12	29	--	--	--	5	--	--	1
Fayettville,	--	--	36	1	--	--	--	--	--	--	--
N.C.	1	7	92	5	1	--	--	--	--	--	--
Columbia,	3	9	70	--	2	--	--	--	--	--	--
S.C.	2	11	37	--	1	2	--	--	--	--	--
Little Rock,	14	15	96	140	4	--	36	--	2	--	9
Ark.	21	28	89	85	7	--	--	--	4	--	25
Monroe,	13	9	49	40	2	--	3	--	--	--	15
La.	15	28	59	28	4	--	--	--	2	--	9
Greenwood,	49	21	101	165	4	3	7	--	2	18	4
Miss.	69	128	145	171	12	1	1	--	6	--	84
Cairo,	11	9	29	31	1	--	1	--	--	--	1
Ill.	17	18	39	29	3	--	--	--	--	--	7
Memphis,	36	22	61	94	5	2	13	--	--	--	1
Tenn.	32	28	58	25	8	--	2	--	2	--	25
Oklahoma City,	36	21	18	10	--	--	2	--	52	--	--
Okla.	4	2	1	--	--	--	--	--	46	--	--
Lubbock,	278	290	153	213	1	18	31	56	774	209	53
Tex.	14	44	13	21	--	1	--	1	735	12	38
Phoenix,	25	69	34	61	--	--	9	--	14	--	--
Ariz.	11	24	24	4	6	--	--	--	44	452	--
Fresno,	67	47	227	245	19	--	--	--	--	12	5
Calif.	12	35	86	25	13	--	--	--	1	723	--
Las Cruces,	2	5	17	35	1	--	--	--	5	--	--
N. Mex.	1	2	2	2	--	--	--	--	11	7	--

1/ First number is tons moved by rail; second is tons moved by truck; and -- means no traffic.

Source: (4).

Appendix table 12--Mileages between selected origins and destinations for cotton shipments

ORIGINS \ DESTINATIONS	Birmingham, Ala.	Atlanta, Ga.	Charlotte, N.C.	Greenville, S.C.	Blackstone, Va.	Worcester, Mass.	Detroit, Mich. (Canada)	Charleston, S.C. (Atlantic ports)	Houston,-Galveston, Tex. (Gulf ports)	Los Angeles, Calif. (Pacific Coast)	New Orleans, La.
	Miles										
Montgomery, Ala.	94	171	407	312	633	1183	811	431	648	2044	320
Augusta, Ga.	314	164	158	112	385	935	758	139	950	2346	622
Fayettville, N.C.	522	372	138	234	167	720	704	181	1169	2559	852
Columbia, S.C.	367	217	93	102	312	867	738	113	1014	2406	695
Little Rock, Ark.	384	506	740	645	911	1401	833	809	459	1691	419
Monroe, La.	365	515	751	656	977	1499	959	797	324	1671	259
Greenwood, Miss.	228	378	121	574	840	1407	834	681	451	1772	276
Cairo, Ill.	322	427	583	531	745	1159	559	716	719	1898	549
Memphis, Tenn.	246	368	602	507	773	1263	709	671	565	1821	393
Oklahoma City, Okla.	718	840	1074	979	1245	1615	1011	1143	471	1349	679
Lubbock, Tex.	960	1110	1346	1251	1529	1959	1355	1403	657	1103	817
Phoenix, Ariz.	1650	1800	2036	1941	2225	2578	1966	2082	1255	393	1494
Fresno, Calif.	2204	2328	2562	2467	2733	3086	2474	2631	1793	217	2073
Las Cruces, N. Mex.	1292	1442	1678	1583	1881	2274	1662	1724	812	751	1136

Source: (24).

Appendix table 13--Ton-miles and transportation fuel requirements for manufactured foods, 1977

Item	Ton-miles 2/			Total Btu's			Diesel fuel			Total
	Rail	Truck	Barge	Rail	Truck	Barge	Rail	Barge	Truck	
	Millions						Million gallons			
Food and kindred products, SIC 20 3/	53,234	41,175	6,818	37,453	100,332	1,989	269	716	13	998
Meat products, SIC 201	4,033	11,401	31	3,045	29,734	5	22	212	--	234
Dairy products, SIC 202	1,250	2,200	7	944	5,998	1	7	43	--	50
Canned and preserved fruits and vegetables, SIC 203	12,709	9,486	247	8,858	24,190	43	64	173	--	237
Grain mill products, SIC 204 4/	13,964	3,584	0	9,734	9,139	0	69	65	0	134
Bakery products, SIC 205	268	760	13	187	1,060	21	1	8	--	9
Sugar, beet, and cane, SIC 206	4,586	989	3,227	3,197	2,521	1,371	23	18	10	51
Confectionary and related products, SIC 207	376	1,714	32	262	4,370	5	2	31	--	33
Beverages and flavoring extracts, SIC 208	5,709	5,850	153	3,979	12,945	26	29	92	--	121
Miscellaneous food preparations, SIC 209	10,354	4,069	3,003	7,217	10,375	517	52	74	3	129

-- = Not applicable.

1/ Commodities are classified by the 1972 Transportation Commodity Code.
2/ From (19). Ton-miles are assumed to increase at an annual rate of 2 percent from 1972 to 1977.
3/ May not equal column totals due to rounding.
4/ Excludes SIC 20421 - Prepared feed; animal, fish, and poultry in SIC 204. Transportation of processed feeds is covered in the farm inputs section.

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