HOUSEHOLD ENERGY CONSUMPTION IN THE UNITED STATES

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Abstract

This paper provides estimates of household energy consumption in the United States in 2019 by adding passenger transportation to residential consumption. It also separates household energy consumption into two components: standard and optional and shows that the latter accounts for 29 percent of the total.

Introduction

All consumption of energy is related to human activity. In the absence of humans, there would be no electricity and fossil fuels would remain underground. People consume energy directly and indirectly. For example, lighting in a home is a direct use of energy by a household while consuming take-out food and purchasing a car are examples of indirect energy consumption. Similarly, lighting in a car factory is an example of direct energy use while manufacturing the car involves both direct and indirect energy consumption. Official statistics allocate energy use to a variety of economic sectors based on their direct energy consumption: residential, commercial, industrial, and transportation. However, transportation is ancillary to the other three sectors as it serves to move people and goods. In this paper I have developed estimates of the direct energy consumption by households in the United States by adding the passenger energy use to residential energy consumption. With this adjustment, the share of the residential sector (now households) in 2019 increased from 21 percent to 37 percent and the share of transportation fell from 29 to 13 percent. I suggest in this paper that in the case of households it may be possible to distinguish between standard and optional energy consumption. I estimate that in the 2019 in the United States 29 percent of household energy consumption was optional.

Household Energy Consumption

The distribution of energy consumption in the US in 2019 is shown in Table 1. The industrial sector consumed the largest share with one third of the total, followed by transportation and the residential sector.

Table 1. Energy Consumption by Sector in the United States in 2019

	Residential	Commercial	Industrial	Transportation	Total
EJ	22.2	19.0	34.5	30.3	106.0
Share (%)	21.0	17.9	32.6	28.5	100.0

Note: End-use consumption includes electricity system energy losses.
Source: EIA (2022), Tables 2-1a and 21-b.

To expand energy consumption in the residential sector into household consumption it is necessary to add the passenger component of transportation. I developed estimates of energy consumption by passengers using data in EIA (2011) and Davis and Boundy (2022). As shown in Table 2, more energy is consumed for the transportation of people (56%) than for the transportation of goods. More than four-fifths of the energy used for passenger travel is consumed by cars, vans, pick-up trucks, and SUVs (light-duty vehicles).

Table 2. US Energy Consumption for Transportation in 2019

Mode	Consumption, PJ		
	Total	Passenger	
		%	PJ
Aviation	2,501	81.1	2,028
Rail	557	8.5	47
Water	1,068	21.1	225
Buses	238	100.0	238
Light-Duty Vehicles	15,999	89.1	14,255
Heavy-duty vehicles	6,589	0	0
Pipelines and Offroad	3,300	3.5	115
Total	30,252	55.8	16,878

Source: EIA (19 March 2011); Davis and Boundy (2022), Tables 2.8, 2.13, and 2.11; Skybrary, www.skybrary.aero/articles/general-aviation-ga.

When the above estimate is added to the energy use by the residential sector, we end with direct household energy consumption (Table 3). With this adjustment, the household sector now becomes the largest single energy user with a share of 37 percent. Of this total, 57 percent is used by buildings and equipment, and 43 percent by passenger transportation. Within the residential component, by far the largest share of energy consumption is for space heating, water heating, and air conditioning which together account for more than three-quarters of residential energy consumption. In 2019, Americans used about one-third of total household energy consumption to get from point A to point B and back, and for passive uses throughout a whole day in a residential building where they spent roughly half a day.

Table 3. Revised Shares of Energy Consumption by Sector in the United States in 2019

	Households	Commercial	Industrial	Transportation	Total
EJ	39.1	19.0	34.5	13.4	106.0
Share	36.9	17.9	32.6	12.6	100.0
Residential	21.0				
Space Heating	*44*				
Water Heating	*20*				
Air Conditioning	*13*				
Lighting	*8*				
*Other**	*15*				
Transportation	15.9				

*None of the other uses individually has a share exceeding 3 percent.
Source: Table 1 and 2; US Census Bureau (2020); EIA (2022), Table 2.2; EIA, "Energy Use Explained: Energy Use in Homes."

Households and Housing Trends

This section identifies some trends in household energy consumption that serve as a background for the separation between standard and optional energy consumption.

Table 4. Summary Statistics on US Households, 1980 and 2019

	1985	2019	Change	
			Value	Percent
Households, 000s	86,789	128,579	41,790	48.2
Families, 000s	62,706	83,482	20,776	33.1
Individuals, 000s	24,083	45,096	21,013	87.2
Mean Household Size	2.69	2.52	- 0.17	- 6.3
Median Household Size	1.83	1.63	- 0.20	- 10.9

Source: US Census Bureau (1986), Tables A and B; US Census Bureau (2019a), Tables H1 and AVG1.

Table 4 highlights the decline in the size of the American household, which fell 6 percent from 2.7 in 1985 to 2.5 percent in 2019. This decline resulted from the high growth of non-family households which outstripped the growth of family households by a factor of 2.6.

Table 5. Summary Statistics of Housing Units

	1985	2019	Change	
			Value	Percent
Occupied Units, 000s	88,425	124,135	35,710	40.4
Detached	*55,076*	*79,335*	*24,259*	*44.0*
Other	*33,349*	*44,800*	*11,451*	*34.3*
Mean Number of Rooms	5.5	5.8	0.3	5.4
Mean Number of Bathrooms	1.5	1.9	0.4	26.7
Mean Square Feet*	1,846	2,095	249	13.5
Median Square Feet*	1,636	1,629	- 7	- 0.4

*Detached Units

Source: US Census Bureau (1988); Us Census Bureau (2020), Table Creator.

Table 5 shows that the opposite trend occurred in the average size of residential units which rose by 14 percent from 1,846 square feet in 1985 to 2,095 square feet in 2019. The increase in the average size was due to two main factors: the rising share of detached units, which increased by 1.3 percentage points, and the increasing share of larger homes. As a result, the gap between the mean and the median size expanded from 200 square feet in 1985 to 466 square feet in 2019.

Demographic, housing, and technological changes that improved energy efficiency, affected a variety of indicators of energy use. From 1985 to 2019 residential energy consumption rose at a slower rate than either population of households. As a result, residential energy consumption per person declined by 5 percent and per household by 12 percent.

Table 6. Selected Indicators of Residential Energy Consumption, 1985 and 2019

	1985	2019	Change	
			Value	Percent
Energy Consumption, EJ	16.9	22.2	5.3	31.4
Population, million	237.9	328.3	90.4	38.0
Households, million	86.8	128.6	41.8	48.2
Energy Consumption, GJ				
Per Person	71.1	67.8	- 3.3	-4.6
Per Household	195.4	173.0	-22.4	-11.5

Source: Tables 1 and 4; USAFacts (2022)."

The next three tables present trends in passenger transportation. Table 7 shows that light-duty motor vehicle registrations increased at 1.7 times the rate of the population 15+. As a result, registrations of these vehicles per 100 people 15+ increased from 85 to 102. In the United States in 2019 on average, each person registered one light-duty vehicle. A similar pattern is noted for households. Registrations increased faster than households by a factor of 1.43 and registrations per household rose from 1.72 to 1.96. Basically, in 2019 an average each US household registered two light-duty vehicles. In 2017, nearly one-quarter of American households registered at least three vehicles and 3.4 percent registered 5 vehicles (Geography.org).

Table 7. Motor Vehicle Registrations of Light-Duty Vehicles

	1980	2019	Change	
			Value	Percent
Total, million	149.5	252.5	103.0	68.9
Population 15+, million	175.3	246.7	71.4	40.7
Households, million	86.8	128.6	41.8	48.2
Per Person 15+	0.85	1.02	0.17	20.0
Per Household	1.72	1.96	0.24	14.0

Source: Davis and Boundy (2022), Table 1-11; US Census Bureau (2019b); Table 6 above; CDC: www.cdc.gov./nchs/data/statab/popo6097.pdf

In 1980, more than one in five LDV produced in the United States was a sedan or station-wagon. No car SUVs were produced, and truck SUVs accounted for less than 2 percent of LDV production. Forty-nine years later, the share of cars in annual LDV production dropped to one-third and that of truck SUVs rose to more than one-third. The share of vans and pick-up trucks increased moderately, but car SUVs now accounted for 12 percent of total annual production, more than one-third of the production of sedans and wagons combined.

Table 8. Production of Light-Duty Vehicles in the United States and Fuel Economy in1980 and 2019

	1980		2019	
	Percent	MPG	Percent	MPG
Car	83.5	20.0	32.7	30.9
Car SUV	0	14.6	11.7	27.5
Van	2.2	14.1	3.4	22.4
Pick-up Truck	12.7	16.5	15.6	19.0
Pick-up SUV	1.6	13.2	36.5	23.5

Source: US Department of Transportation (2021), Table 1-20.

The change in the vehicle mix was associated with an increase in the weight of all LDVs. After declining from the mid-1970s to the early 1980s, vehicle weight began to rise steadily. From 1985 to 2019 the average LDV weight rose by nearly one-third (over 1,000 pounds). The increase was by far largest for pick-up trucks.

For the other vehicles the increase ranged between 300 and 500 pounds. The LDV design of the late 1970s and early 1980s incorporated a deep concern for fuel costs. The 2019 vehicle design shows no concern for either fuel costs or environmental impact.

Table 9. Average New Light-Duty Vehicle Weight by Vehicle Type in the United States: 1975, 1985 and 2019, Pounds

	1975	1985	2019	Change: 1975-85		Change: 1985-2019	
				Value	Percent	Value	Percent
All Light-Duty Vehicles	4,060	3,271	4,287	- 789	- 19.4	1,016	31.1
Sedan/Wagon		3,100	3,500			400	12.9
Car SUV		3,500	3,800			300	8.6
Van		4,000	4,500			500	12.5
Pick-Up Truck		3,600	5,100			1,500	41.7
Truck SUV		4,000	4,500			500	11.2
Average MPG	13.1	21.3	25.3	8.2	62.6	4.0	18.8

Source: EPA (2022), Figure 3.5 and Tables 3.1 and 3.2

Standard versus Optional Household Energy Consumption

This section separates household consumption into two major components: standard and optional. I define standard energy consumption as what is needed to satisfy household needs. For example, the household need in the residential sub-sector is shelter and household equipment that offer security from the elements and an adequate level of comfort. Similarly, motor vehicles serve the purpose of satisfying people's basic transportation needs. Details of the methodology employed in this paper are fund in the appendix. In this section I just summarize the results.

Table 10 shows that 29 percent of total household energy consumption in the United States in 2019 may be considered as optional. This share varies by sub-sector. The share of optional energy consumption for shelter-related needs is about one-third (8 percentage points) higher that the share for transportation needs. Nearly two-thirds of the optional energy use originates in the residential sub-sector and one-third in passenger transportation. Optional household energy consumption is equivalent to 11.2 EJ. To put it into perspective, this energy would be sufficient to satisfy the total combined energy consumption of France and Belgium in 2020.

Table 10. Standard and Optional Household Consumption in the United States, 2019

	EJ			Percent		
	Residential	Transp.	Total	Residential	Transp.	Total
Standard	15.1	12.8	27.9	68.0	75.7	71.4
Optional	7.1	4.1	11.2	32.0	24.3	28.6
Total	22.2	16.9	39.1	100.0	100.0	100.0

Conclusions

In its 2021 *International Energy Outlook*, the US Energy Information Administration (EIA) projected that world energy consumption could increase by close to 50 percent from 2020 to 2050. The policy response to the growth of energy use has been largely focused on the supply side: more exploration, more drilling, more nuclear power, and more renewables. While the pressures originate from the demand side, the response is directed almost exclusively on the supply side. This approach guarantees that the transition from fossil fuels to renewable energy will be a long one. As shown by the consequences of the Russian-Ukrainian war and the willingness of OPEC+ to exercise its strengthening market power, an energy transition focused on the supply side will likely lead to greater instability in the world economic system. I suggest that a shift of focus towards the demand side is long overdue and needs to include both technological advances and behavioral changes. The potential on the behavioral side is quite large. Analyzing the pattern of direct household energy consumption in the United States in 2019, I estimated that 29 percent of that consumption is optional, two-thirds of which originates in the residential sub-sector and one-third in passenger transportation. Because the full benefits of behavioral changes will materialize over a long period of time as they require changes in the stock of housing and motor vehicles, policies directed at the demand side should be developed and implemented with a sense of urgency.

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Appendix

Residential. I started with the relationship between number of bedrooms in a housing unit and the corresponding average size in 2019 (US Census Bureau, 2020) for number of bedrooms from 0 to 4+. Then I separated households into three types: non-family (singles), couples, single-parents, and assigned a number of rooms to each household on the basis of CMHC's guidelines (Statistics Canada) T Finally, I applied the energy consumption per square foot based on data in EIA's Residential Energy Consumption Survey (RECS). I used the 2015 survey (Table CE 1.1) because the consumption data for 2020 are not yet available. Since the RECS measures on site energy consumption, which excludes electricity energy losses, I derived the distribution of energy consumption by housing unit size and applied it to the total energy consumption in the residential sector. I estimated that 32 percent of energy consumption in the residential sector may be treated as optional. The share of optional energy consumption is smaller than that of optional residential unit size because of economies of scale, as shown in Table A-2.

Table A-1. Household Size by Type, Number of Bedrooms, and Residential Unit Size, 2019

HH Size	Bedrooms	Square Feet
Non-Family		
1	0-1	700
Married Couples		
2	1+	1,000
3	2	1,228
4	2+	1,500
5	3	1,785
6	3+	2,000
7+	4	2,223
Single Parents		
2	2	1,228
3	2+	1,500
4	3	1,785
5	3+	2,000
6	4	2,223
7+	4+	2,500

Table A-2. Housing Unit Size and Energy Consumption in 2019

Square Feet	Thousands of BTUs
700	121.7
1,000	114.3
1,228	109.5
1,500	105.0
1785	101.0
2,000	96.0
2,223	91.0

Passenger Transportation

Highway

Vehicles per Household. I used a similar approach for passenger transportation, starting from estimates of light-duty vehicles (LDV) per household. According to data from the US Department of Transportation (2021, Table 1-11), LDV registrations in 1980 amounted to 1.72 per household. By 2019 this value rose to 1.96. I assumed that the opposing effects of two demographic and economic developments during this period (rising employment rate and declining household size) were fully offsetting, which implies that the difference in car ownership per household is treated as optional. Because the only factor affecting energy consumption is the number of LDV per household, the percentage change in fuel consumption is equal to the percentage change in the number of vehicles per household: a decline of 12.2 percent.

Vehicle Weight. Then I looked at average annual miles per LDV (Davis and Boundy, 2022, Table 4.3). The record shows that MPV fluctuated within a fairly narrow range from 1970 to 2019. From 1970 to 1980, MPV fell from 10,053 to 9,383 in response to rising fuel prices. They recovered to 10,001 in 1986 and peaked at 11,901 in 1998. They retreated to 11,204 in 2009 during the Great Recession, rose again to 11,607 in 2018 and then declined slightly to 11,579 in 2019. Because of this pattern, choosing any year as the standard would have been a totally arbitrary decision. Therefore, I used the 2019 value for both the standard and the actual.

Vehicle Weight and Composition of Vehicles Inventory. Finally, I analyzed the pattern of miles per gallon for LDV and identified three main determining factors: technology, vehicle weight, and composition of the vehicle inventory. I treated technology as exogenous and focused on the other two factors. Data from the US Department of Transportation show two trends in motor vehicle ownership since 1980: a shift away from sedans/wagons to pick-up trucks, car SUVs, and truck SUVs and an increase in vehicle weight, particularly for pick-ups. To measure the effect of increasing weight on fuel economy, I relied on the study by Cheah and others (2007). They estimated that a 20 percent reduction of vehicle weight can be achieved without affecting vehicle performance and that a maximum 35 percent reduction in vehicle weight is possible by 2035. I assumed a weight reduction of 15 percent from 2007 to 2019 for each type of LDV. Cheah and others (2007) also estimated that the "combined city/highway fuel consumption will decline by 0.31L/100km per every 100 kg weight reduction for a car, and 0.34L/100km for light trucks" (p. 43). To measure the effect of changing vehicle weights, I estimated the average miles per gallon for all LDV in 2019, with actual and adjusted MPG by vehicle type using the 2019 distribution of registrations by vehicle type. The results suggest that the extra 15 percent weight of LDV in 2019 led to a reduction of 7.9 percent in fuel economy (and in total fuel consumption since miles per vehicle are assumed to be equal for the actual and standard cases). To estimate the combined effect of changes in the distribution of the vehicle inventory by type of vehicle I repeated the calculations under two standards. For the first standard I assumed that, starting in 1980, the percentage distribution of new LDVs was repeated each successive year up to 2019. This assumption leads to a distribution of the stock of LDVs in 2019 equal to the distribution of new LDVs purchased in 1980. I made this assumption because 1980 is close to the end of the energy crises of the 1970s and incorporates the behavioral responses to those events. In effect I am transferring to 2019 the automotive purchasing behavior of 1980. I estimated that the combined change in vehicle weight and distribution by vehicle type led to a reduction in fuel economy of 18 percent. I then repeated the exercise by replacing 1980 with 2000. If the standard is 2000, the fuel economy reduction is 13 percent.

Combining the three effects yields a fuel saving of 28 percent when the standard is the inventory composition in 1980, and 24 percent when the standard is 2000. I used 25 percent. In other words, if in 2019 light vehicle registration per household was equal to that in 1980, vehicle weight was 15 percent lower than in 2007, and the vehicle mix in the inventory was an average of 1980 and 2000, total fuel consumption by light-duty vehicles would have been 25 percent lower.

Other Modes of Transportation

For rail, water, and bus passenger transportation I assigned all energy use to standard. According to Statista, 80 percent of flights in 2019 were for leisure. Since some transportation for leisure is part of normal life (the standard), I assigned only 25 percent of aviation energy consumption to optional. I used the same approach to offroad transportation.

Summary

Table A-3 summarizes my estimates of the standard and optional energy consumption by mode of passenger transportation in the US in 2019. The optional component accounts for 24.2 percent of total consumption. Nearly 87 percent of the optional component is generated by light-duty vehicles.

Table A-3. Energy Consumption in Passenger Transportation in the United States in 2019: Standard versus Optional

	Energy Consumption, PJ		
	Standard	Optional	Total
Light-Duty Vehicles	10,691	3,564	14,255
Aviation	1,521	507	2,028
Rail	47	0	47
Water	225	0	225
Bus	238	0	238
Off-Road	86	29	115
Total	12,808	4,100	16,908