Principles of Energy Conversion

Part 2. Energy Perspectives

January 15, 2018

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Article 3

Energy Information

3.1 "lies, damned lies, and statistics"

"There are three kinds of lies: lies, damned lies, and statistics."[1] It is exceeding easy to obtain misleading or incorrect statistical information on energy from the popular press, which includes the internet. Aside from political and technical biases, there are conflicting data sets on existing resource availability. For projections of energy utilization, there are dozens of growth models available.

One criteria of discerning the accuracy of statistical data is to ask 'is the primary purpose of this source to provide data or to provide analysis and commentary on data?'. If the purpose is the latter, then use caution. The data provided will nearly always be a subset of a larger data set and you will not know for certain what information has been excluded.

Below are a few, generally reliable sources of information[2] on energy, historical and projected energy utilization, energy resource availability, and efficiency:

- DOE Energy Information Agency (EIA)
  https://www.eia.gov/

- EIA Annual Energy Review (AER)
  https://www.eia.gov/totalenergy/data/annual/index.php

- EIA Forecasts & Analysis
  https://www.eia.gov/outlooks/aeo/

- EIA Levelized Cost of New Generation Resources
  https://www.eia.gov/outlooks/aeo/electricity_generation.php

- International Energy Agency
  http://www.iea.org

- BP Statistical Review of World Energy - 2016
  BP Statistical Review (url changes annually)

- Lawrence Livermore National Lab
  https://flowcharts.llnl.gov/

- US Geological Survey
  https://energy.usgs.gov/

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[1] Phrase popularized by Mark Twain in *Chapters from My Autobiography* (1906).
[2] weblinks accessed January 15, 2018

3.2 Historical U.S. Energy Consumption

Figure 5. Primary Energy Consumption by Source, 1635-2008
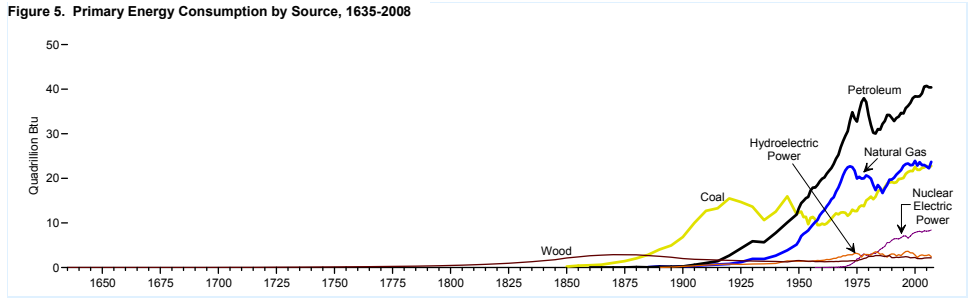
Figure 3.1: Historical U.S. energy consumption by source, 1635-2008. [1]
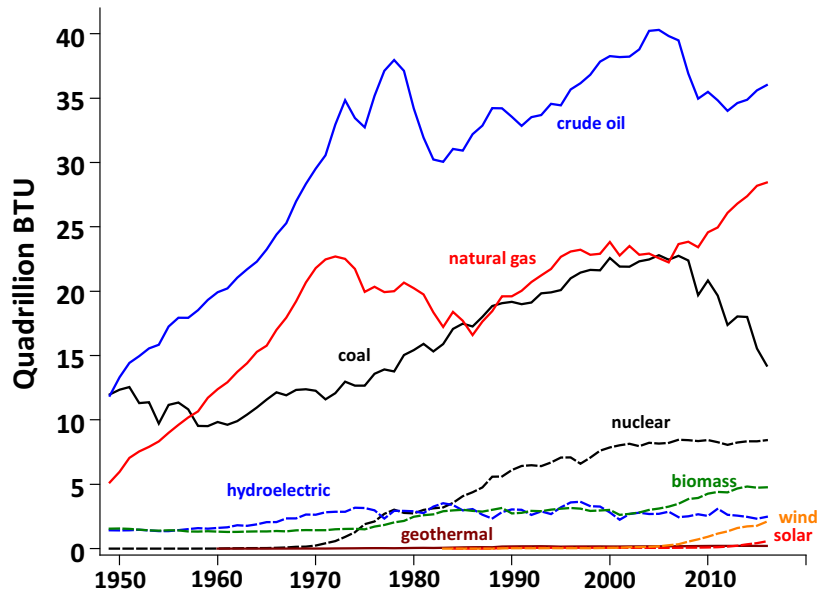
Figure 3.2: Historical U.S. energy consumption by source, 1949-2016. [2]

3.2.1 Production and Consumption by Source

Production:

By Major Source, 1949-2010
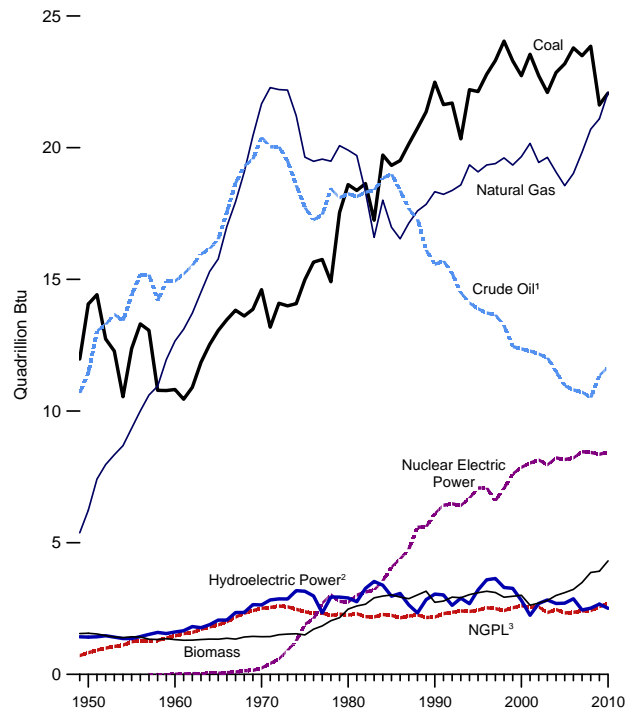
Energy Information Agency [3]

Consumption:

By Major Source, 1949-2010
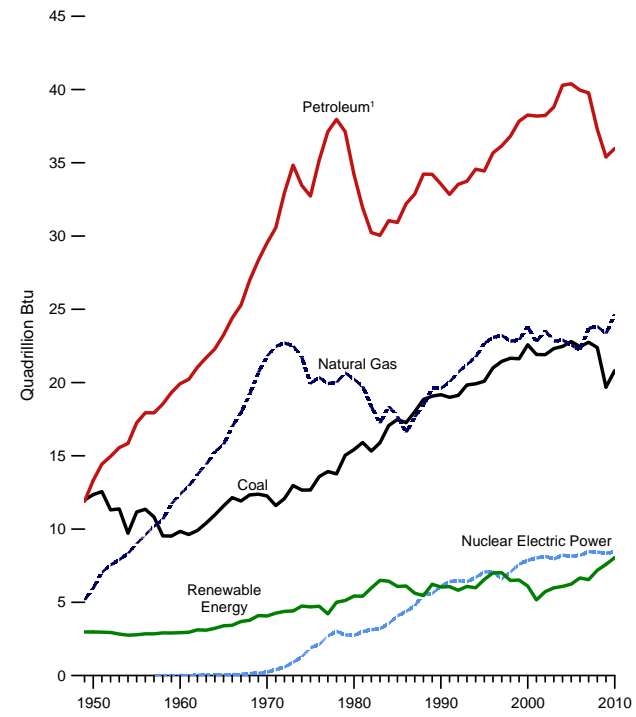
3.2.2 Energy Consumption and Expenditure

Energy Consumption, 1949-2010

Energy Expenditures, 1970-2009

Energy Consumption per Person, 1949-2010

Energy Expenditures per Person, 1970-2009

Energy Information Agency [3]

3.2.3 Household Energy Consumption

Table 2.5 Household Energy Consumption and Expenditures by End Use and Energy Source, Selected Years, 1978-2005

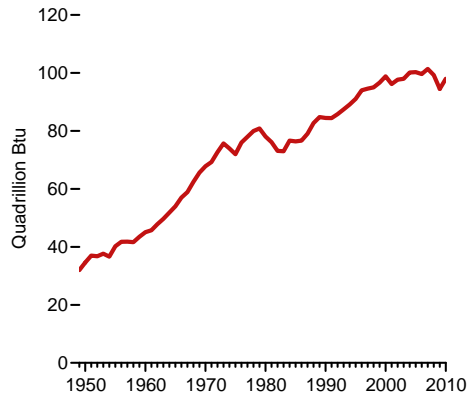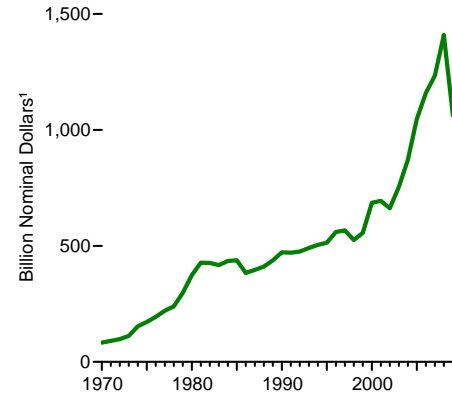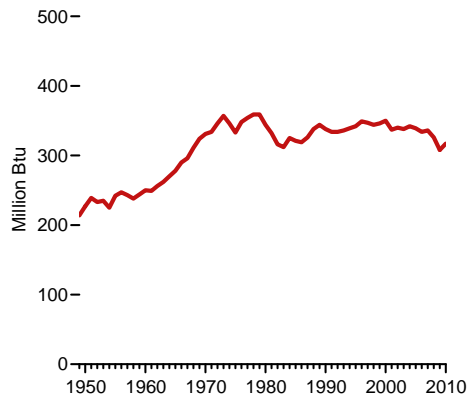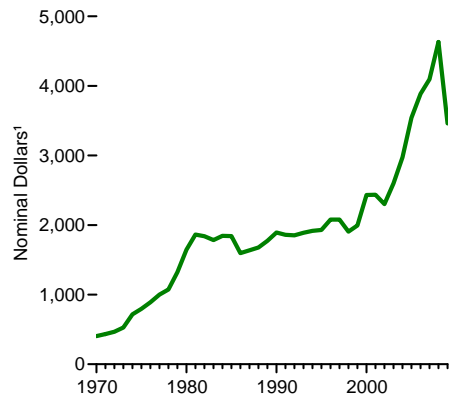| Year	Space Heating [1] Natural Gas	Elec- tricity [5]	Fuel Oil [6]	LPG [7]	Air Conditioning [2] Electricity [5]	Water Heating Natural Gas	Elec- tricity [5]	Fuel Oil [6]	LPG [7]	Appliances [3,4] Natural Gas	Elec- tricity [5]	LPG [7]	Total Natural Gas [2]	Elec- tricity [5]	Fuel Oil [4,6]	LPG [7]	Wood [8]
							Consumption (quadrillion Btu)										
1978	4.26	0.40	2.05	0.23	0.31	1.04	0.29	0.14	0.06	0.28	1.46	0.03	5.58	2.47	2.19	0.33	NA
1979	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.31	2.42	1.71	.31	NA
1980	3.41	.27	1.30	.23	.36	1.15	.30	.22	.07	.36	1.54	.05	4.97	2.48	1.52	.35	.85
1981	3.69	.26	1.06	.21	.34	1.13	.30	.22	.06	.43	1.52	.05	5.27	2.42	1.28	.31	.87
1982	3.14	.25	1.04	.19	.31	1.15	.28	.15	.06	.43	1.50	.05	4.74	2.35	1.20	.29	.97
1984	3.51	.25	1.11	.21	.32	1.10	.32	.15	.06	.35	1.59	.04	4.98	2.48	1.26	.31	.98
1987	3.38	.28	1.05	.22	.44	1.10	.31	.17	.06	.34	1.72	.04	4.83	2.76	1.22	.32	.85
1990	3.37	.30	.93	.19	.48	1.16	.34	.11	.06	.33	1.91	.03	4.86	3.03	1.04	.28	.58
1993	3.67	.41	.95	.30	.46	1.31	.34	.12	.05	.29	2.08	.03	5.27	3.28	1.07	.38	.55
1997	3.61	.40	.91	.26	.42	1.29	.39	.16	.08	.37	2.33	.02	5.28	3.54	1.07	.36	.43
2001	3.32	.39	.62	.28	.62	1.15	.36	.13	.05	.37	2.52	.05	4.84	3.89	.75	.38	.37
2005	2.95	.28	.75	.32	.88	1.41	.42	.14	.15	.43	2.77	.05	4.79	4.35	.88	.52	.43
							Expenditures (billion dollars [9])										
1978	11.49	3.53	8.06	1.05	3.97	2.88	3.15	0.56	0.36	0.93	19.24	0.25	15.30	29.89	8.62	1.66	NA
1979	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	17.84	32.56	10.73	2.06	NA
1980	13.22	3.78	10.48	1.78	5.84	4.51	4.45	1.76	.57	1.91	26.74	.44	19.77	40.81	12.24	2.80	NA
1981	16.62	3.93	9.44	1.78	6.23	5.13	4.94	1.94	.51	2.17	29.70	.52	24.03	44.80	11.39	2.81	NA
1982	17.74	4.21	8.80	1.69	6.23	6.51	5.00	1.28	.54	2.58	31.29	.52	26.96	46.74	10.07	2.75	NA
1984	20.66	4.62	8.51	2.00	7.06	6.63	6.44	1.09	.58	2.31	36.36	.54	29.78	54.48	9.60	3.12	NA
1987	18.05	5.53	6.25	1.85	9.77	6.02	6.45	.94	.50	2.02	39.83	.46	26.15	61.58	7.21	2.81	NA
1990	18.59	6.16	7.42	2.01	11.23	6.59	7.21	.83	.65	2.03	46.95	.48	27.26	71.54	8.25	3.14	NA
1993	21.95	8.66	6.24	2.81	11.31	8.08	7.58	.74	.58	1.98	53.52	.42	32.04	81.08	6.98	3.81	NA
1997	24.11	8.56	6.57	2.79	10.20	8.84	8.99	1.04	.89	2.86	60.57	.36	35.81	88.33	7.61	4.04	NA
2001	31.84	8.98	5.66	4.04	15.94	11.31	8.47	1.15	.69	3.83	66.94	.86	46.98	100.34	6.83	5.60	NA
2005	31.97	7.42	10.99	6.35	25.26	15.57	11.13	2.00	3.28	4.80	80.92	1.37	52.37	124.74	12.99	11.00	NA

Energy Information Agency [3]

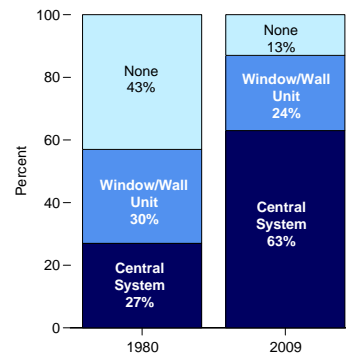| Appliance	Year													Change
	1978	1979	1980	1981	1982	1984	1987	1990	1993	1997	2001	2005	2009	1980 to 2009
Total Households (millions)	77	78	82	83	84	86	91	94	97	101	107	111	114	32
	Percent of Households													
Space Heating - Main Fuel [1]														
Natural Gas	55	55	55	56	57	55	55	55	53	52	55	52	50	-5
Electricity [2]	16	17	18	17	16	17	20	23	26	29	29	30	35	17
Liquefied Petroleum Gases	4	5	5	4	5	5	5	5	5	5	5	5	5	0
Distillate Fuel Oil [3]	20	17	15	14	13	12	12	11	11	9	7	7	6	-9
Wood	2	4	6	6	7	7	6	4	3	2	2	3	2	-4
Other [4] or No Equipment	3	2	2	3	3	3	3	2	2	2	2	3	1	-1
Air Conditioning - Equipment														
Central System [5]	23	24	27	27	28	30	34	39	44	47	55	59	63	36
Window/Wall Unit [5]	33	31	30	31	30	30	30	29	25	25	23	25	24	-6
None	44	45	43	42	42	40	36	32	32	28	23	16	13	-30
Water Heating - Main Fuel														
Natural Gas	55	55	54	55	56	54	54	53	53	52	54	53	51	-3
Electricity [2]	33	33	32	33	32	33	35	37	38	39	38	39	41	9
Liquefied Petroleum Gases	4	4	4	4	4	4	3	3	3	3	3	4	4	0
Distillate Fuel Oil [3]	8	7	9	7	7	6	6	5	5	5	4	4	3	-6
Other or No Water Heating	0	0	1	1	1	1	1	1	1	1	0	0	1	0
Appliances														
Refrigerator [6]	100	NA	100	100	100	100	100	100	100	100	100	100	100	0
One	86	NA	86	87	86	88	86	84	85	85	83	78	77	-9
Two or More	14	NA	14	13	13	12	14	15	15	15	17	22	23	9
Separate Freezer	35	NA	38	38	37	37	34	34	35	33	32	32	30	-8
Clothes Washer	74	NA	74	73	71	73	75	76	77	77	79	83	82	8
Clothes Dryer	59	NA	61	61	60	62	66	69	70	71	74	79	79	18
Natural Gas	14	NA	14	16	15	16	15	16	14	15	16	17	15	1
Electric	45	NA	47	45	45	46	51	53	57	55	57	61	63	16
Dishwasher	35	NA	37	37	36	38	43	45	45	50	53	58	59	22
Range/Stove/Oven	99	NA	99	100	99	99	99	100	100	99	100	99	99	0
Natural Gas	48	NA	46	46	47	46	43	42	33	35	35	35	34	-12
Electric	53	NA	57	56	56	57	60	59	63	62	62	62	60	3
Microwave Oven	8	NA	14	17	21	34	61	79	84	83	86	88	96	82
Electronics														
Television	NA	NA	98	98	98	98	98	99	99	99	99	99	99	1
One	NA	NA	47	51	49	46	40	35	34	32	27	21	21	-26
Two	NA	NA	38	34	35	34	35	36	36	37	36	35	33	-5
Three or More	NA	NA	14	14	15	18	23	28	28	29	36	43	44	30
Video Cassette Recorder (VCR)	NA	NA	NA	NA	NA	NA	NA	NA	NA	88	[7] 90	80	51	NA
Digital Video Recorder (DVR)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	43	NA
Computer	NA	NA	NA	NA	NA	NA	NA	NA	NA	35	56	68	76	NA
One	NA	NA	NA	NA	NA	NA	NA	NA	NA	29	42	45	41	NA
Two or More	NA	NA	NA	NA	NA	NA	NA	NA	NA	6	15	23	35	NA
Printer	NA	NA	NA	NA	NA	NA	NA	NA	5	12	49	59	60	NA

Energy Information Agency [3]

Share of Households With Selected Appliances, 1980 and 2009
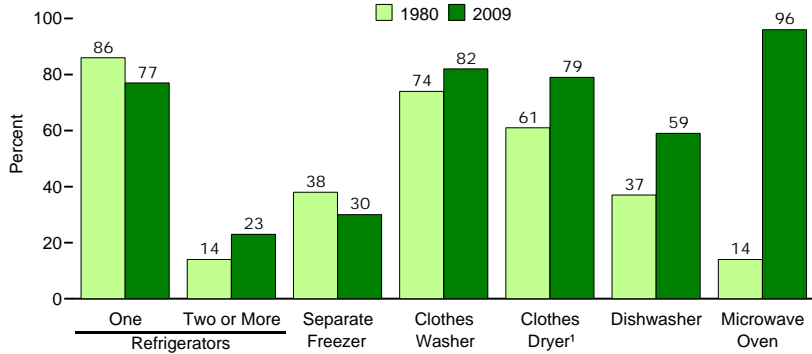
Share of Households With Selected Electronics, 1997 and 2009

Space Heating by Main Fuel, 2009

Air-Conditioning Equipment, 1980 and 2009
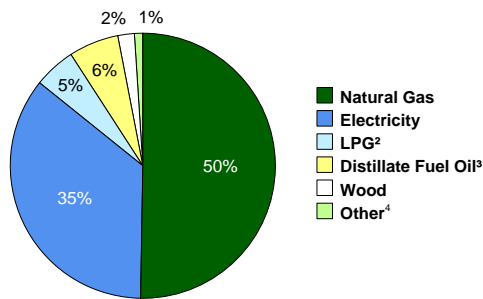
Energy Information Agency [3]

3.3 Historical U.S. Proved Energy Reserves & Resources

The definition of an energy resource, such as coal, shale oil, or petroleum, is based on that portion which can be economically extracted. The portion of resource ready for extraction is referred to as reserves. There are a number of subdivisions of energy resources. [4]

Illustration from Probstein and Hicks [4]

Total Resources: comprised of identified and undiscovered resources.

Identified Resources: demonstrated and inferred resources.

Demonstrated Resources: proved plus indicated resources.

Proved Resources: resources that have been measured by detailed geological surveys.

Indicated Resources: resources based on some measurements and on estimates of geological projection.

Demonstrated Reserve Base: proved and indicated reserves.

Hypothetical Resources: inferred by extrapolation of geological data into unexplored regions known to contain some amount of the resource.

Speculative Resources: geological extrapolation into undiscovered areas.

The figure cited for the total resource can vary depending upon the amount of exploration in am area and the economic viability of resource extraction. For example, as the price of a barrel of crude oil rises, the amount of shale oil that can be recovered (demonstrated reserve base) will increase.
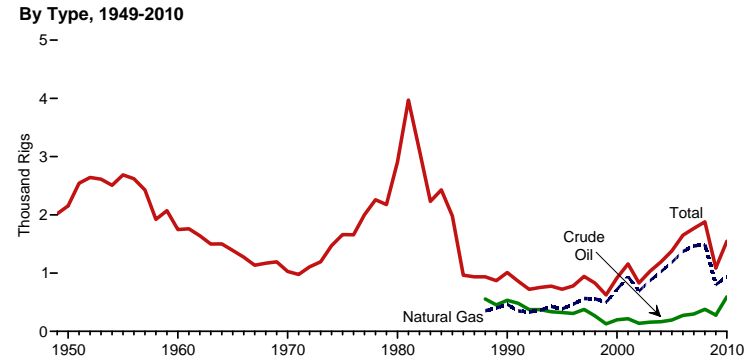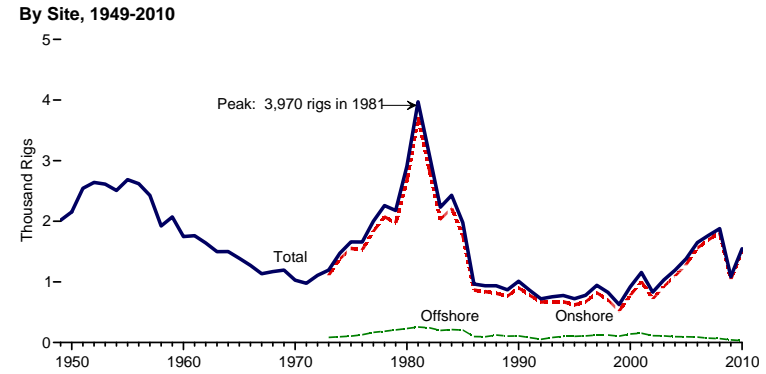
3.3.1 Crude Oil & Natural Gas
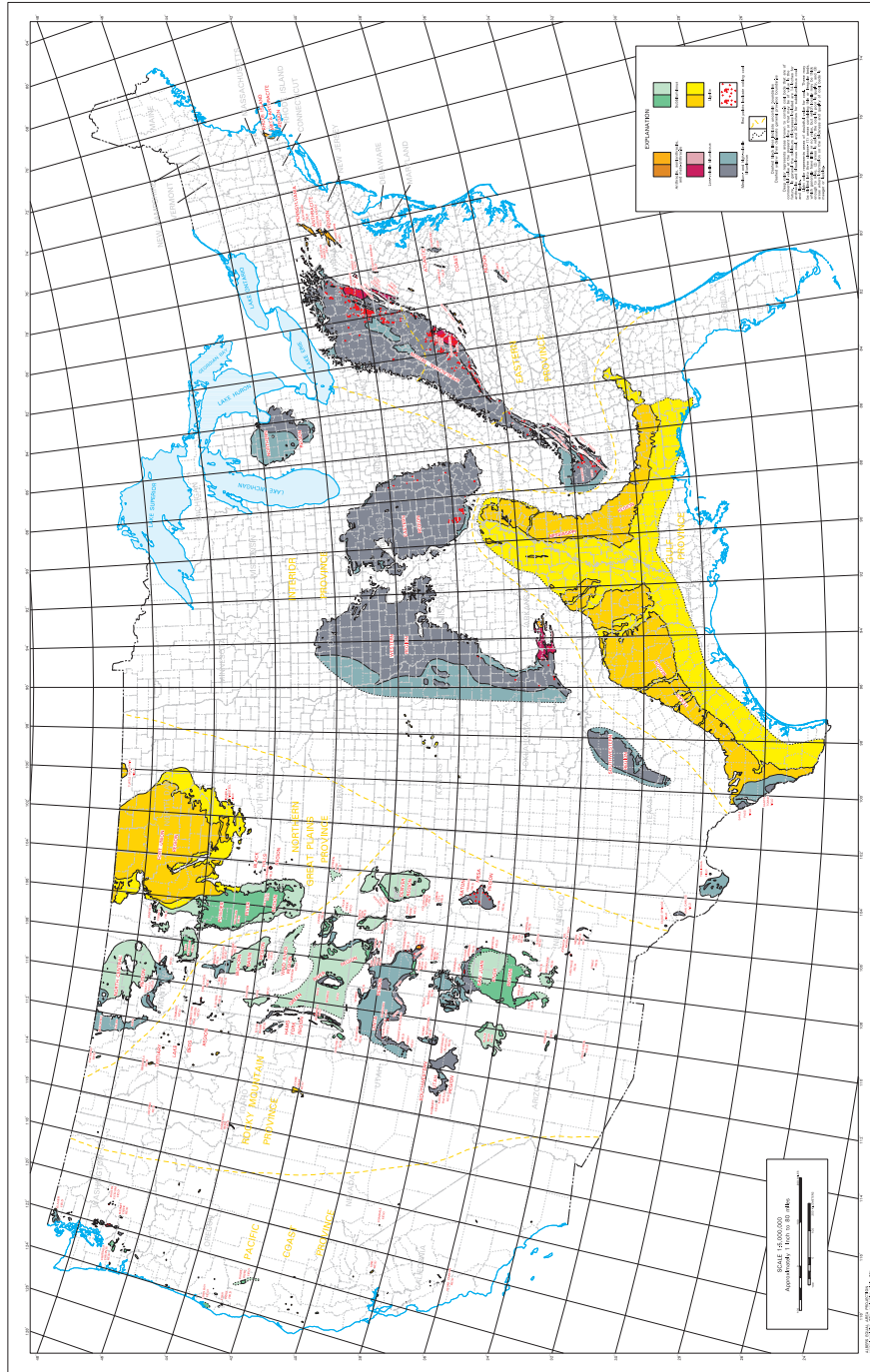
Crude Oil & Natural Gas Proved Reserves:

Total, 1949-2009

Operational Crude Oil & Natural Gas Rigs:

By Site, 1949-2010

By Type, 1949-2010

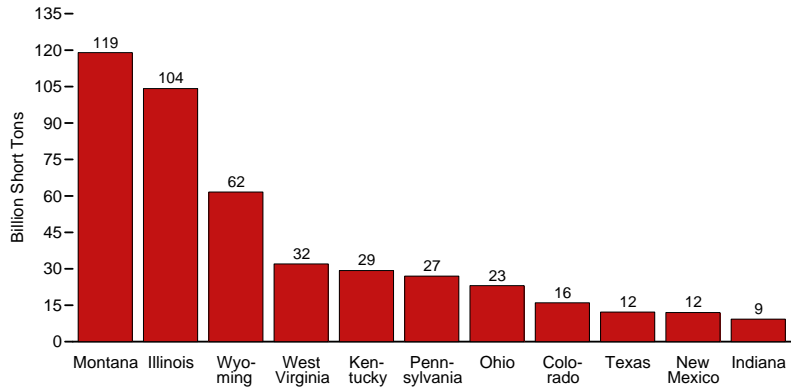

Energy Information Agency [3]
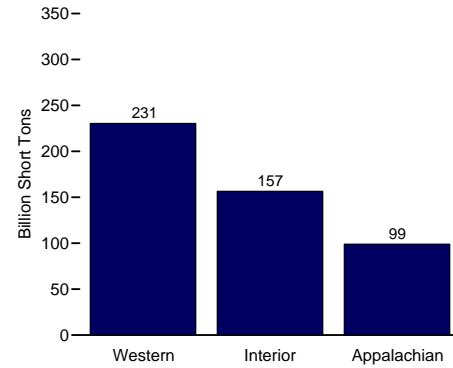
3.3.2 Coal Reserves

Tully [5]

3.3.3 Demonstrated Coal Reserves - 2009
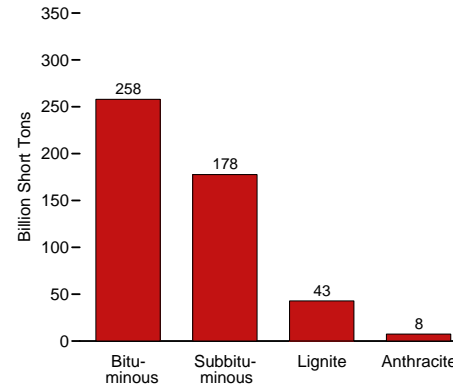
By Key State

By Region

West and East of the Mississippi
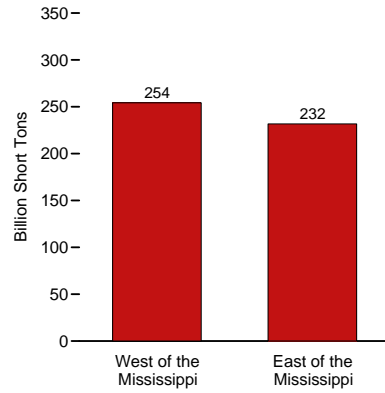
By Mining Method

By Rank

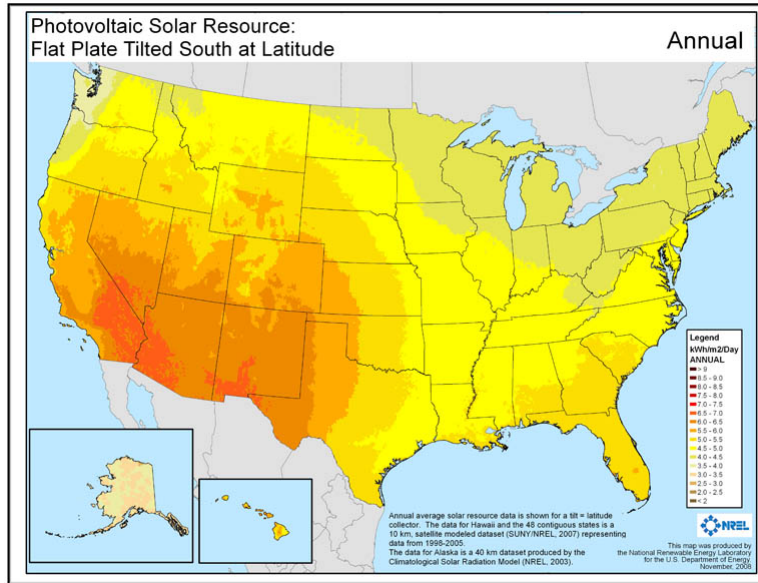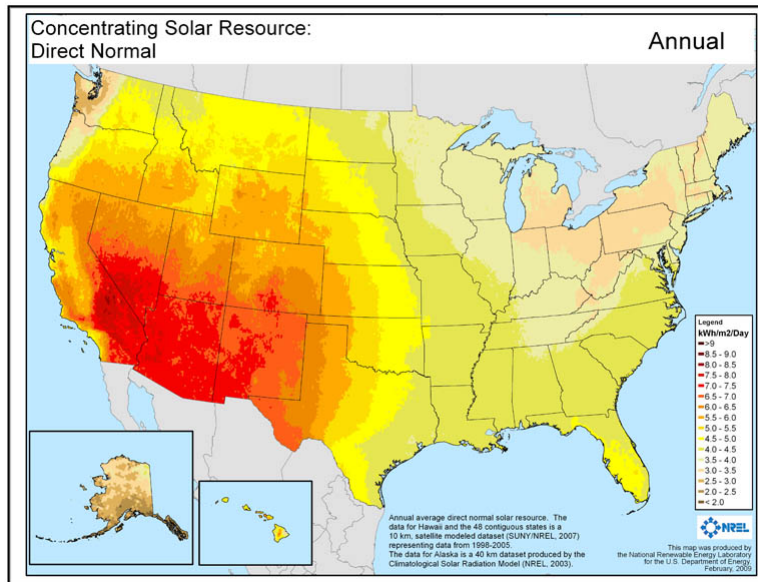Energy Information Agency [3]
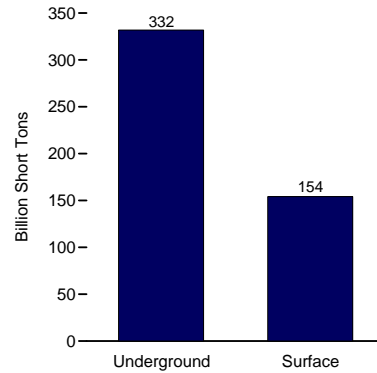
3.4 U.S. Renewable Energy Resources

3.4.1 Photovoltaic Flat Plate

3.4.1.1 Concentrated Solar Power

National Renewable Energy Laboratory [6]

3.4.2 Hydro-Power
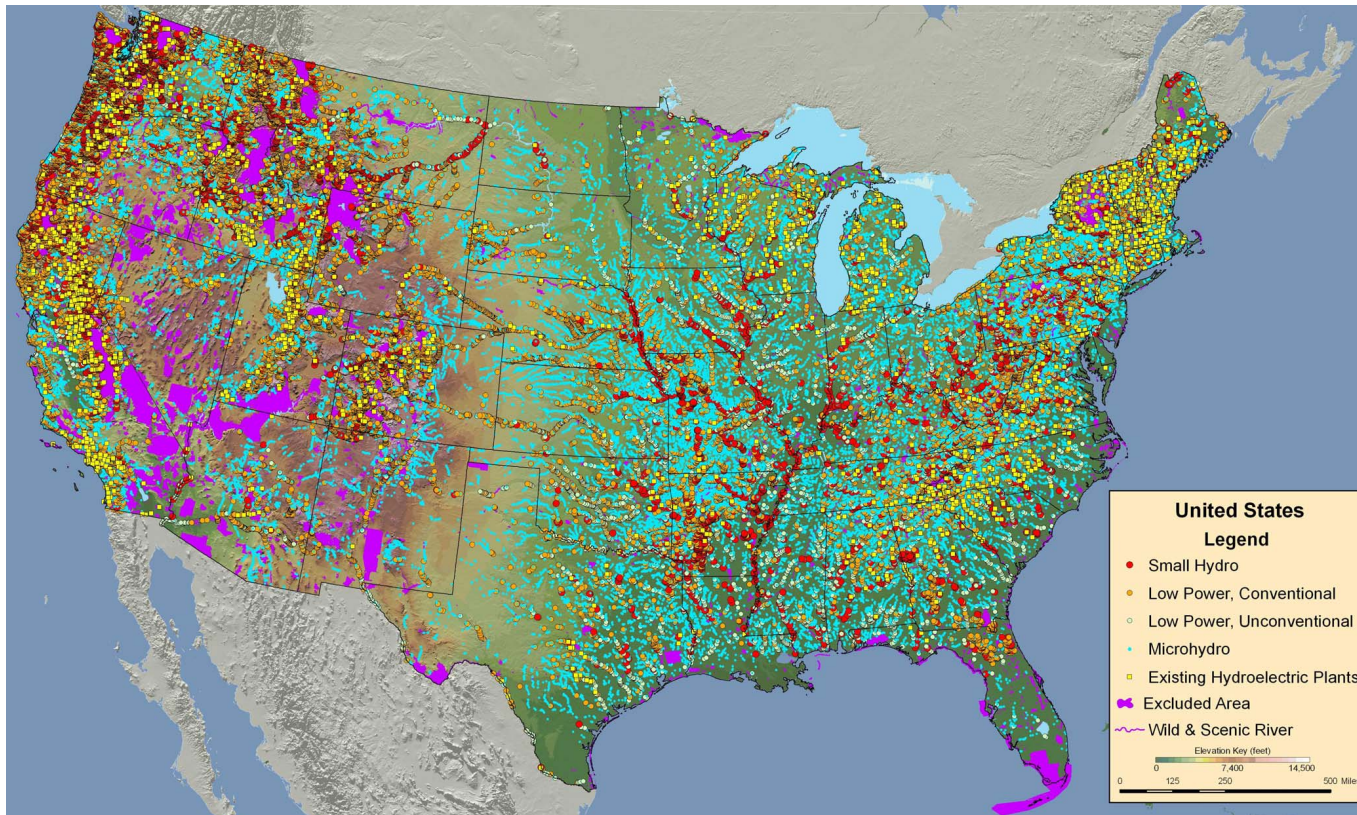
Department of Energy [7]
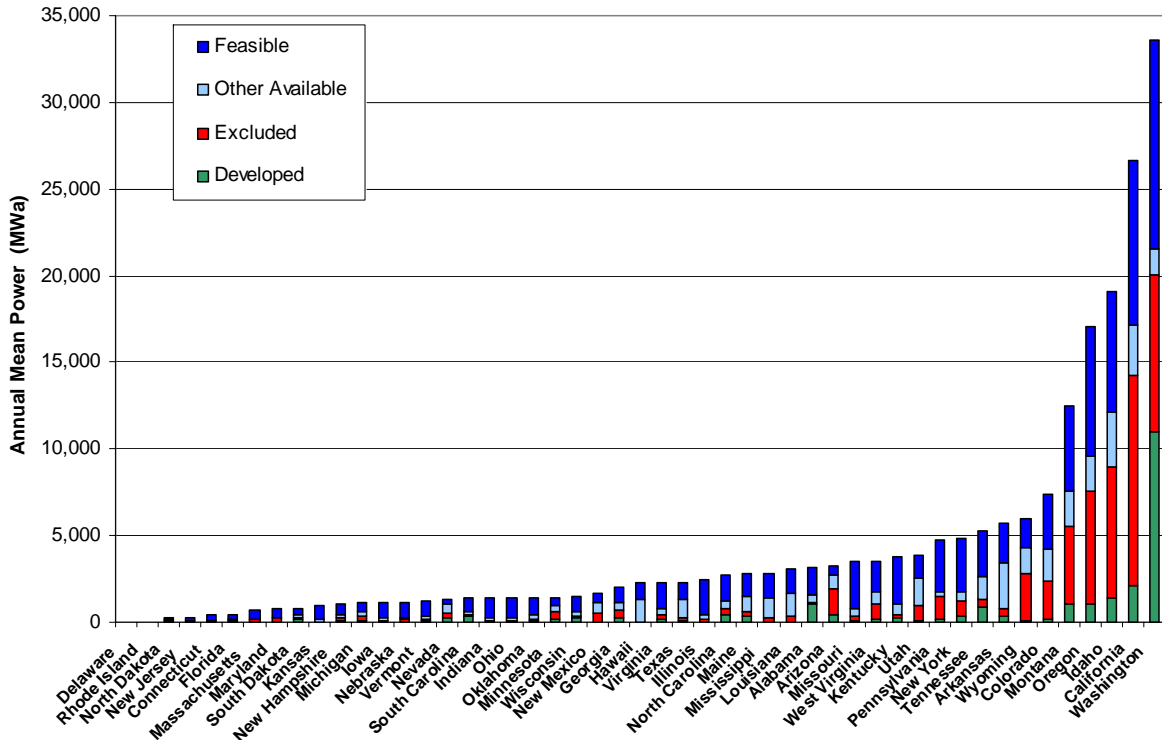
Department of Energy [7]

3.5 Energy Flow Diagrams

3.5.1 U.S. Energy Flow - 1970

(Units: Million barrels per day oil equivalent)

Figure 1.6 The sources and utilization of fuel energy in the United States, 1970. *(From charts presented to the Congressional Joint Committee on Atomic Energy at the May 3, 1973 meeting.)*

Culp [8]

3.5.2 U.S. Energy Flow - 1980
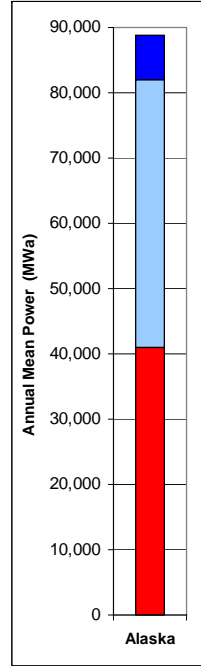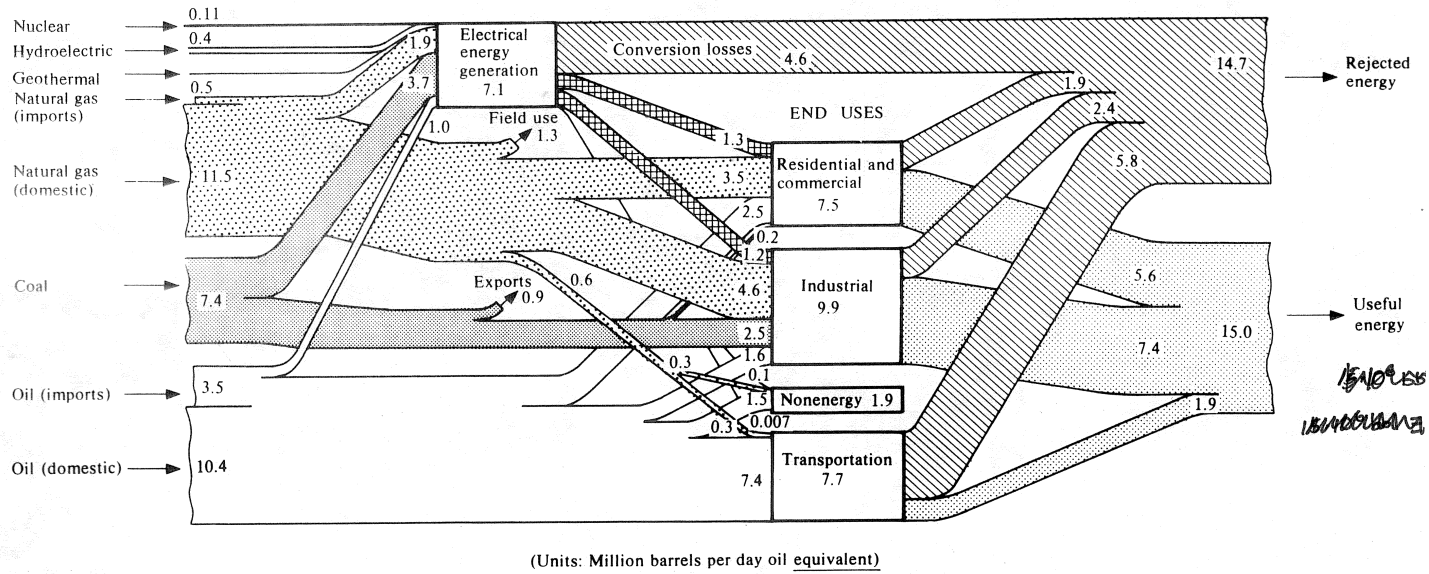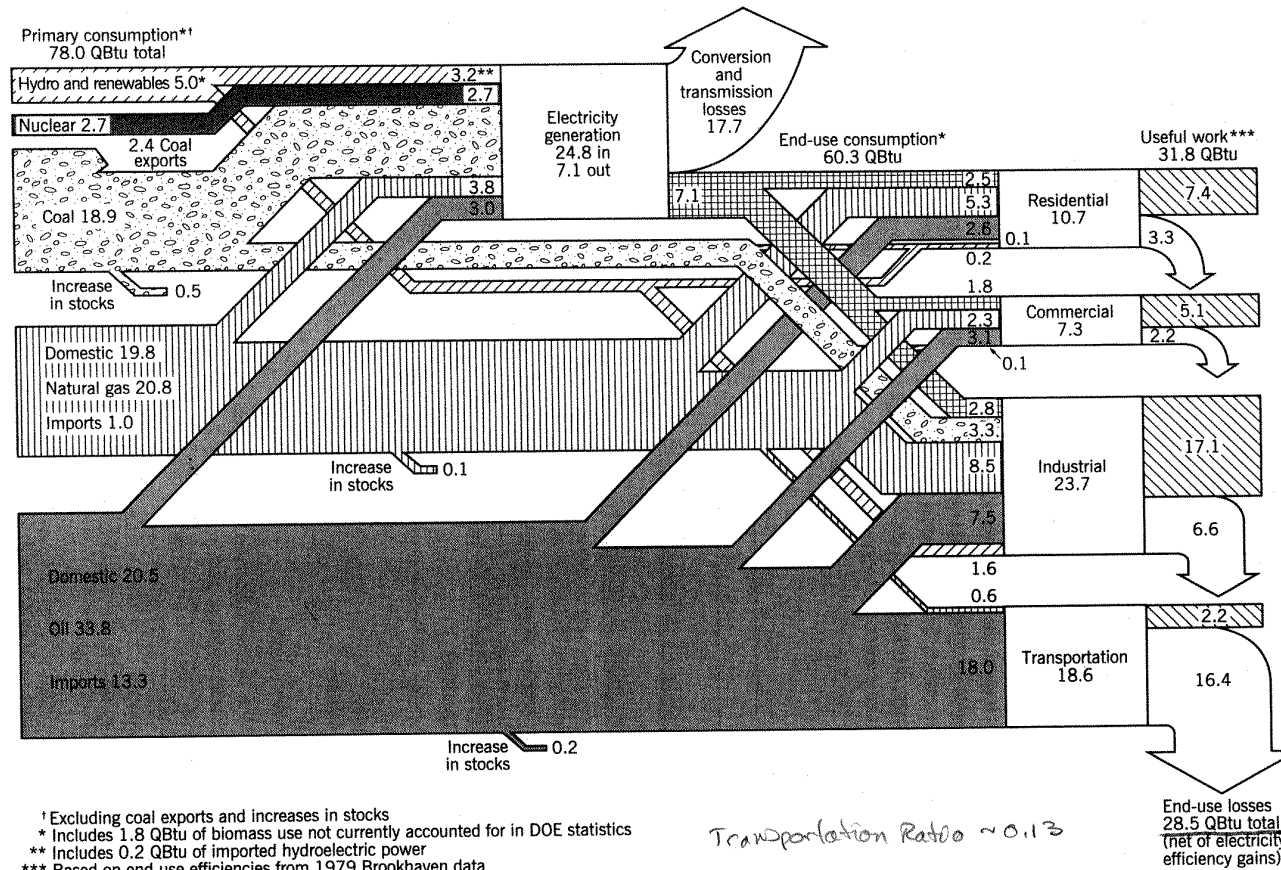
Primary consumption*†
78.0 QBtu total

Hydro and renewables 5.0* 3.2**
2.7

Nuclear 2.7

2.4 Coal exports

Coal 18.9

Increase in stocks 0.5

Domestic 19.8

Natural gas 20.8

Imports 1.0

Increase in stocks 0.1

Domestic 20.5

Oil 33.8

Imports 13.3

Increase in stocks 0.2

Conversion and transmission losses
17.7

Electricity generation
24.8 in
7.1 out

3.8
3.0

7.1

End-use consumption*
60.3 QBtu

Useful work***
31.8 QBtu

Residential
10.7

2.5
5.3
2.6
0.1
0.2
1.8

7.4

3.3

Commercial
7.3

2.3
3.1
0.1

5.1
2.2

Industrial
23.7

2.8
3.3
8.5
7.5
1.6
0.6

17.1

6.6

Transportation
18.6

18.0

2.2

16.4

End-use losses
28.5 QBtu total
(net of electricity efficiency gains)

† Excluding coal exports and increases in stocks
  * Includes 1.8 QBtu of biomass use not currently accounted for in DOE statistics
 ** Includes 0.2 QBtu of imported hydroelectric power
*** Based on end-use efficiencies from 1979 Brookhaven data

Transportation Ratio ~ 0.13

Kraushaar and Ristinen [9]

3.5.3 U.S. Energy Flow - 2002

Electrical imports* 0.08
Nuclear 8.1
Hydro 2.6   2.5
0.04
Biomass/other** 3.2   0.9
1.7
5.7
Natural gas 19.6
Net imports 3.6
Coal 22.6   20.0
0.4 Imports
0.9
U.S. petroleum and NGPL 14.9
Imports 24.3

Electric power sector 38.2
Distributed electricity 11.9
Electrical system energy losses 26.3
0.5
8.3
7.8
Bal. no. 0.1
0.2
Export 1.0
0.1   0.7
Bal. no. 0.3
Export 2.0
2.2   4.0   5.2
Bal. no. 0.9

8.4
Residential/commercial 19.6
3.4
2.1
Industrial 19.0
0.02
Nonfuel 5.9
0.02
25.6
Transportation 26.5

4.9   3.8   Lost energy 56.2
21.2
14.7   Useful energy 35.2
15.2
5.3

*Net fossil-fuel electrical imports.
**Biomass/other includes wood, waste, alcohol, geothermal, solar, and wind.

Ristinen and Kraushaar [10]

3.5.4 U.S. Energy Flow – 2008 (LLNL)

Estimated U.S. Energy Use in 2008: ~99.2 Quads

Lawrence Livermore National Laboratory
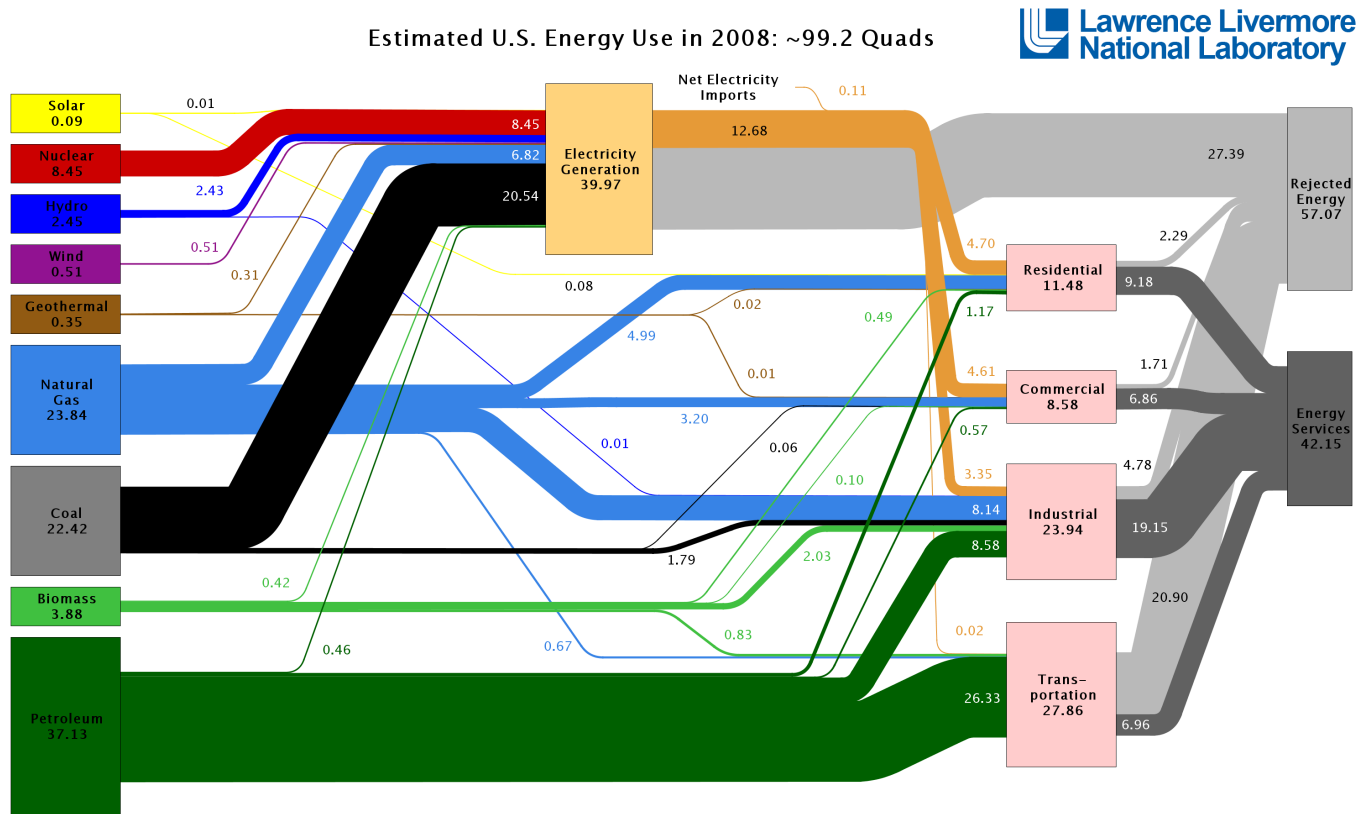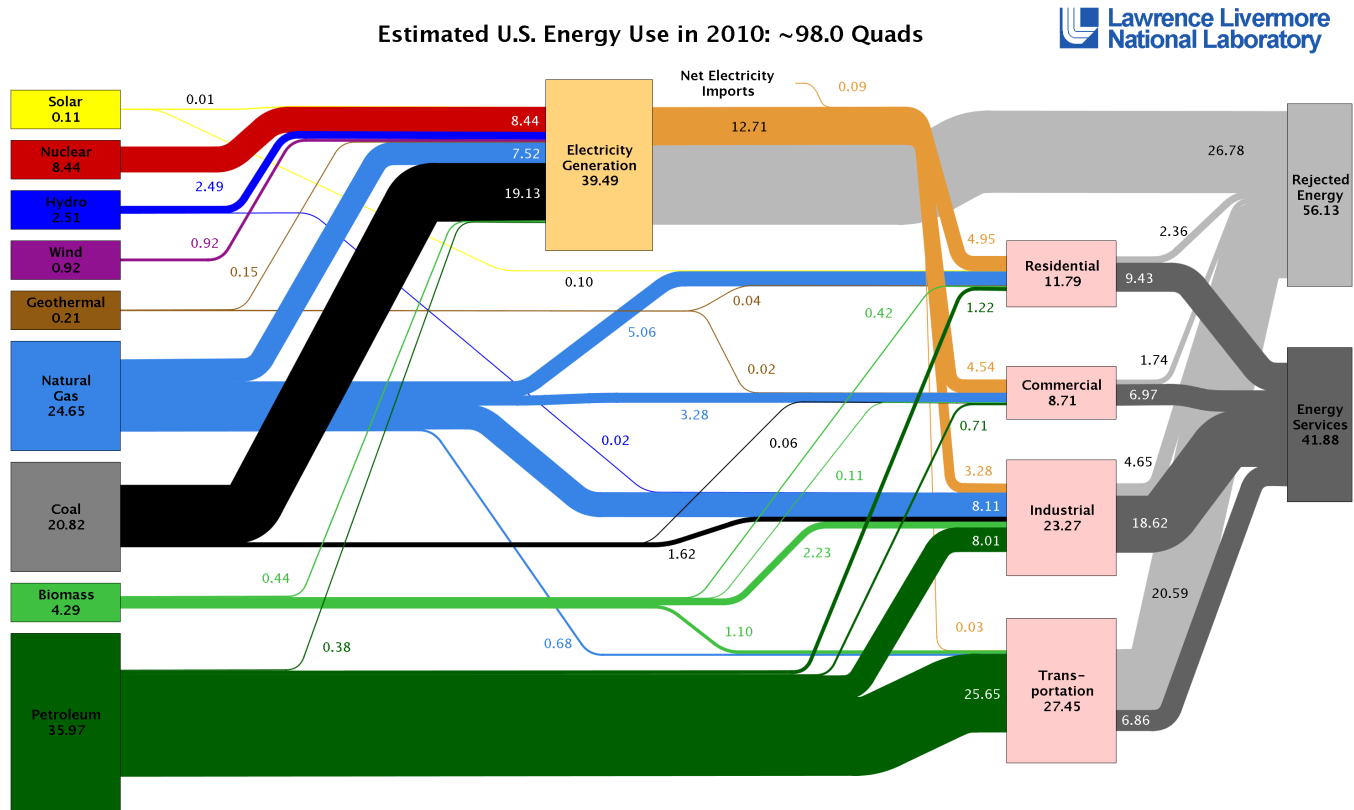
Source: LLNL 2009. Data is based on DOE/EIA–0384(2008), June 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self–generation. EIA reports flows for non–thermal resources (i.e., hydro, wind and solar) in BTU–equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL–MI–410527
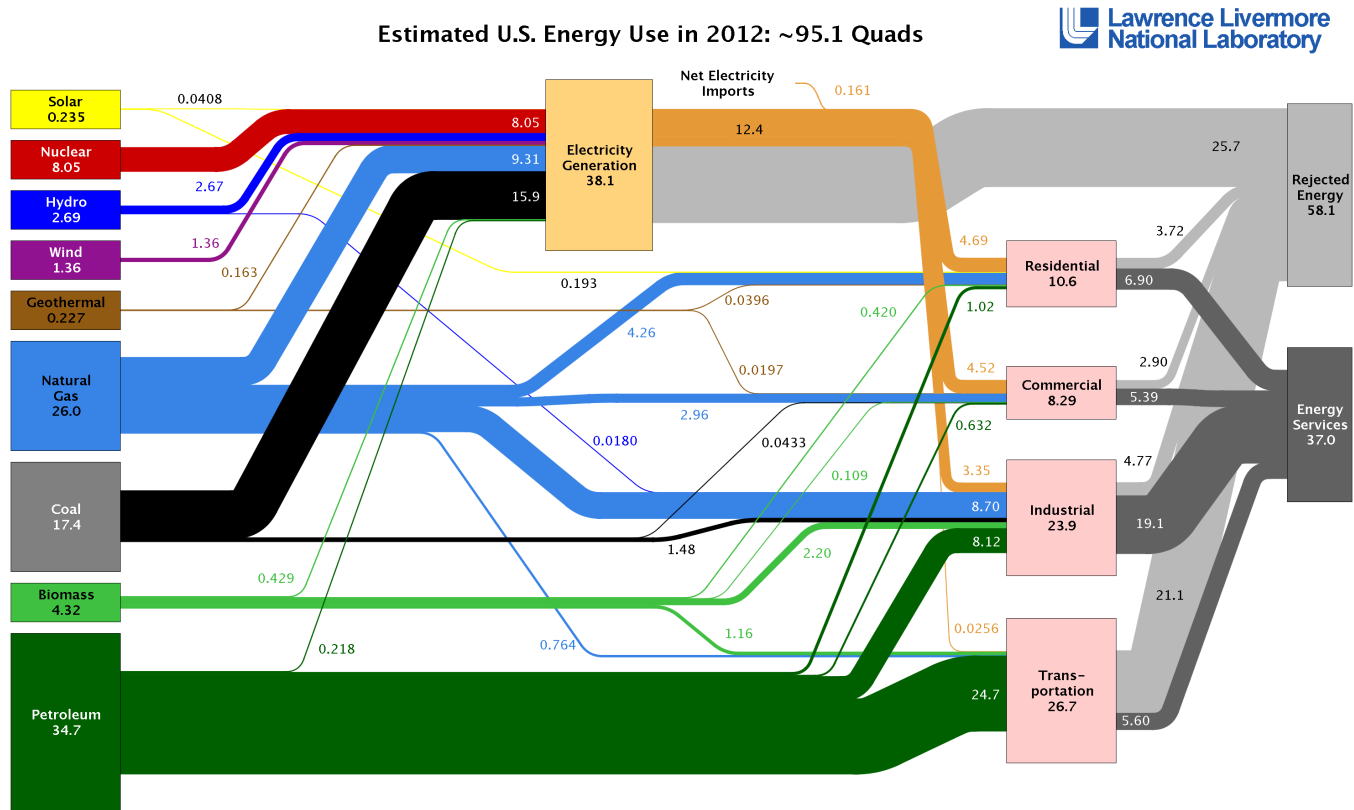
Lawrence Livermore National Lab [11]

Estimated U.S. Energy Use in 2010: ~98.0 Quads

Source: LLNL 2011. Data is based on DOE/EIA-0384(2010), October 2011. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for hydro, wind, solar and geothermal in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." (see EIA report for explanation of change to geothermal in 2010). The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

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3.5.6 U.S. Energy Flow - 2012 (LLNL)

Estimated U.S. Energy Use in 2012: ~95.1 Quads
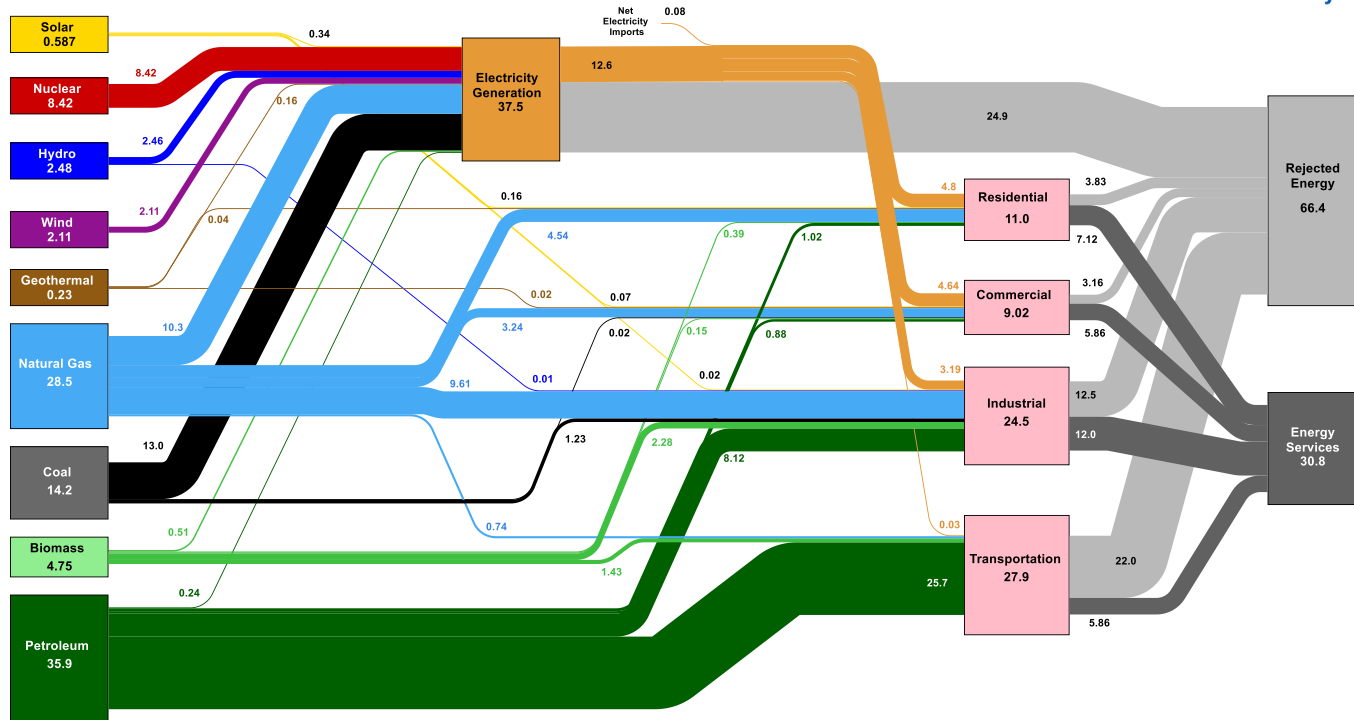
Lawrence Livermore
National Laboratory

Source: LLNL 2013. Data is based on DOE/EIA-0035(2013-05), May, 2013. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

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3.5.7 U.S. Energy Flow - 2016 (LLNL)

Estimated U.S. Energy Consumption in 2016: 97.3 Quads

Source: LLNL March, 2017. Data is based on DOE/EIA MER (2016). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. This chart was revised in 2017 to reflect changes made in mid-2016 to the Energy Information Administration's analysis methodology and reporting. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector, and 49% for the industrial sector which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

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Bibliography

[1] Energy Information Agency. Annual Energy Review 2008. U.S. Department of Energy, June 2009.

[2] Annual Energy Review Web Site. U.S. Department of Energy, January 2017.

[3] Energy Information Agency. Annual Energy Review 2010. U.S. Department of Energy, October 2011.

[4] Ronald F. Probstein and R. Edwin Hicks. *Synthetic Fuels*. Dover Publications, Mineola, New York, 2006.

[5] John Tully. Coal Fields of the Conterminous United States. USGS Open-File Report OF 96-92, US Geological Survey, 1996.

[6] National Renewable Energy Laboratory. Renewable Resource Data Center, August 2012.

[7] Department of Energy. Feasibility Assessment of the Water Energy Resources of the United States for New Low Power and Small Hydro Classes of Hydroelectric Plants. DOE-ID-11263, Energy Efficiency and Renewable Energy, Wind and Hydropower Technologies, January 2006.

[8] Archie Culp, Jr. *Principles of Energy Conversion, 2nd ed.* The McGraw-Hill Companies, Inc., 1991.

[9] Jack J. Kraushaar and A. Ristinen, Robert. *Energy and Problems of a Technical Society*. John Wiley & Sons, Inc., 2nd edition, 1993.

[10] Robert A. Ristinen and Jack J. Kraushaar. *Energy and the Environment*. John Wiley & Sons, Inc., 2nd edition, 2006.

[11] Lawrence Livermore National Lab. Energy Flow, August 2012.