Sankey Diagram

A part of notes on Linear Algebra, by Zhigang Suo, Harvard University

A **Sankey diagram** is a visual display of the flow of a scalar. In a Sankey diagram, the width of each branch of the flow is **proportional** to the magnitude of the scalar.

Wiki Sankey diagram.
Video instruction on how to read energy flow chart.
My notes on scalar set

Flow of a scalar. Water flows from mountains to oceans. Commodities flow from producers to consumers. Money changes hands. Electric charge flows in circuits. The flow of a scalar can often be complex, from many sources, via many branches, to many sinks.

An excellent way to visualize the flow of a scalar is to plot a Sankey diagram, in which the width of each branch of the flow is proportional to the magnitude of the scalar, and different branches are additive. Thus, a Sankey diagram visualizes the flow by taking advantage of the scalar properties: additivity, scalability, and proportionality.

Energy flow chart. Every year the Lawrence Livermore National Laboratory publishes a Sankey diagram of the flow of energy in the United States. The diagram is called the energy flow chart.

Energy is a commodity, and therefore forms a scalar set. The diagram uses the quad as a unit of energy. This unit converts to the SI unit of energy as

1 quad = 1.055×10^{18} J = 1055 PJ.

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Here J is the unit of energy in the SI system, J = joule, which is about the energy needed to raise an apple by a meter. P is a prefix and stands for peta, P = 10^{15}.

The consumption of energy in 2015 was a little under 100 quads. This amount has been nearly constant for many years.

Energy flows from producers to consumers. Energy came from multiple sources: solar, nuclear, hydro, wind, geothermal, natural gas, coal, biomass, and petroleum. Energy overwhelmingly came from fossil fuels: 28.3 quads of natural gas, 15.7 quads of coal, and 35.4 quads of petroleum. The contribution from solar was minute: 0.532 quads.

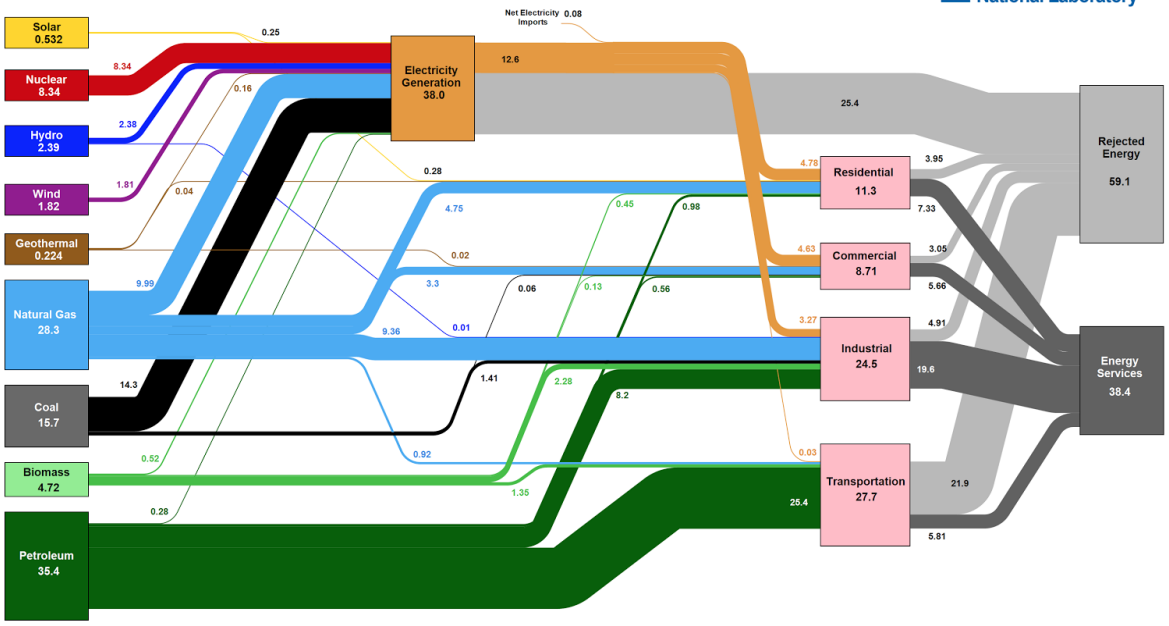
Of the 38 quads of energy used to generate electricity, 14.3 quads came from coal, and 8.34 quads came from nuclear.

Of the 35.4 quads of energy from petroleum, 27.7 quads went for transportation.

Nearly 60% energy was wasted.

Estimated U.S. Energy Consumption in 2015: 97.5 Quads

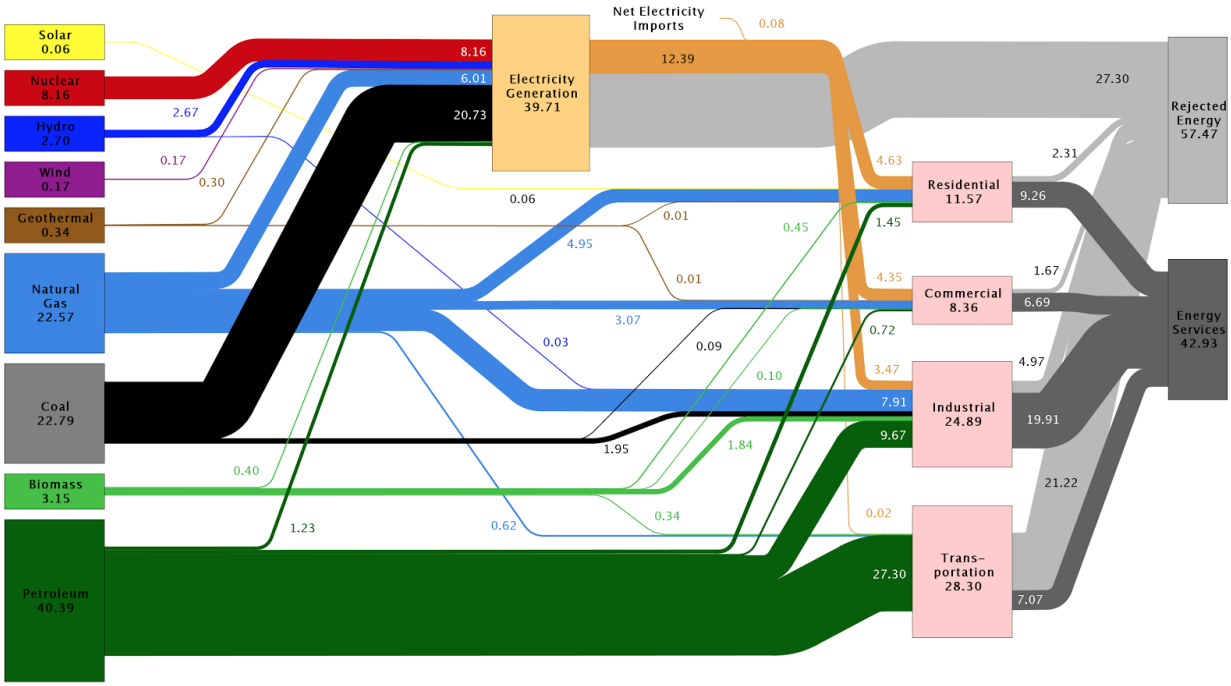
Lawrence Livermore National Laboratory



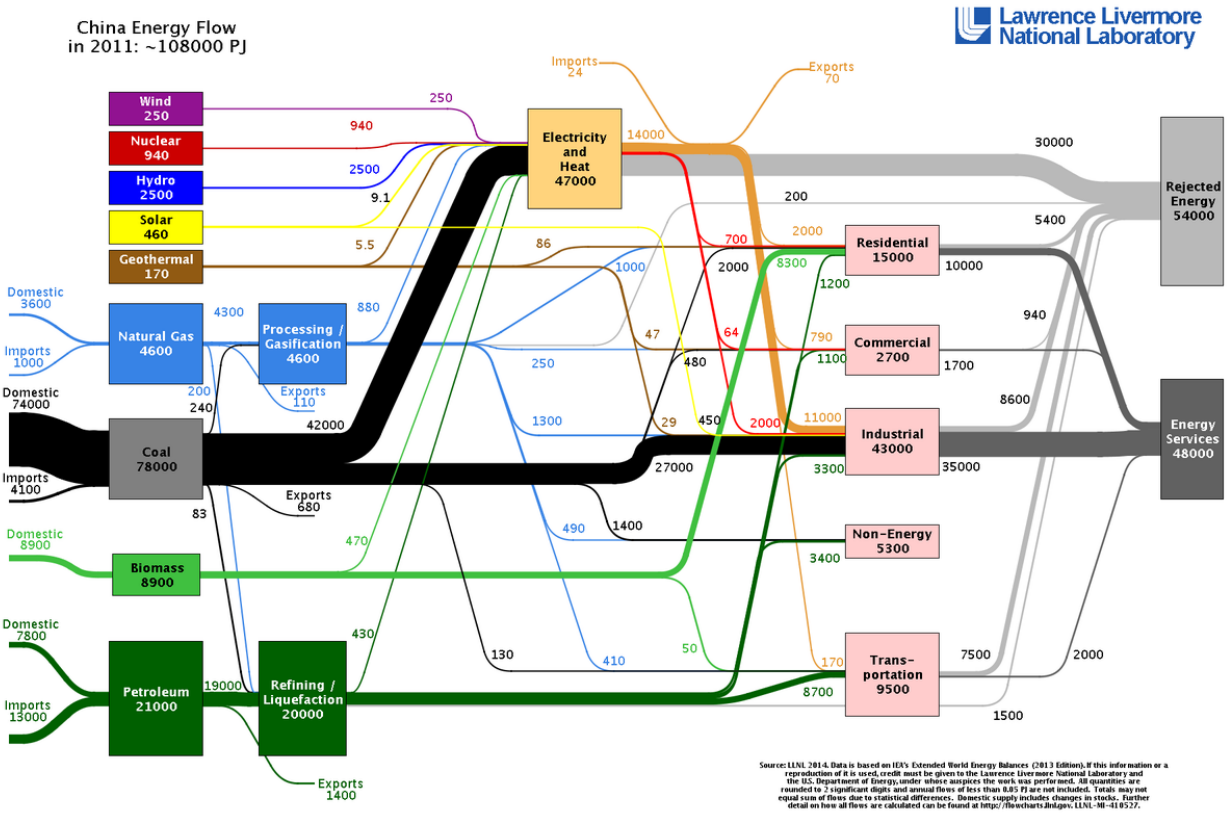
Source: LLNL March, 2016. Data is based on DOE/EIA MER (2015). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail 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 sector, 65% for the commercial sector, 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

Estimated U.S. Energy Use in 2005: ~100.4 Quads

Lawrence Livermore National Laboratory



Source: LLNL 2008. Data is based on DOE/EIA-0384(2007), June 2008. 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



Energy flow charts in different years. A comparison between the 2015 chart and 2005 chart reveals many important trends. The total energy consumption has drops somewhat, reflecting the stability of the US economy and more efficient use of energy. Nuclear, hydro, and geothermal remain unchanged. Solar and wind increase nearly tenfold. What will happen in another ten years?

Natural gas increases, but coal and petroleum drop.

Once again, about 60% energy is wasted.

Energy flow charts of different countries. Total energy consumptions of the US and China are comparable, but the use of coal in China is much higher than that of the US. The consequence is obvious when you visit China: the smog. The relation between coal and smog is so predictable that the government can order blue sky on demand, simply by shutting down factories for a period.

The widths of coal in the two charts also tell another story. In the US, the coal is mainly used to generate electricity, with a small portion for other industrial use. In China, significant portion of coal is used in industry.