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Introduction to Global Energy Sources and Sinks

On a global basis, there is a complex interplay between the sources of energy that we tap into as humans and the corresponding end-uses of that energy. To consider this global energy system, it may help to begin with a study of the sources and end-uses (or "sinks") themselves. The charts and diagrams presented below are a snapshot in time (2011). Energy sources and end-uses in this activity are quantified either in absolute units in exajoules (EJ = 1 x 1018 joules), or on a relative basis, as percentages. Data in this activity comes from the Lawrence Livermore National Laboratory under the US Department of Energy published in 2014 and the United Nations 4th Inter-governmental Panel on Climate Change (IPCC) published in 2007. According to this IPCC report, "The main goal of all energy transformations is to provide energy services that improve quality of life and productivity. A supply of secure, equitable, affordable and sustainable energy is vital to future prosperity." Predicting how these graphs might shift in the future is an important consideration for this exercise.

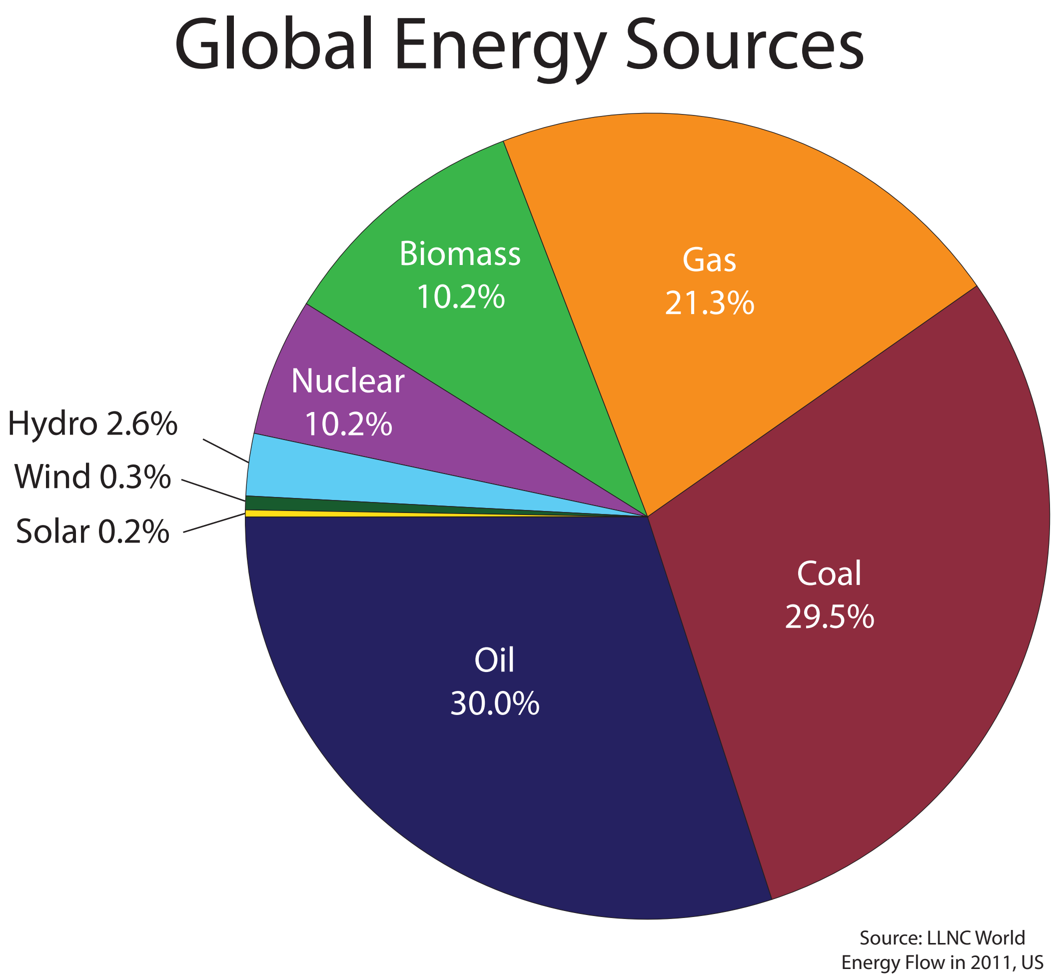

Figure 1. Global energy sources, quantified on a percentage basis. For 2011, the total of these sources was 507 EJ. "Gas" primarily refers to natural gas.

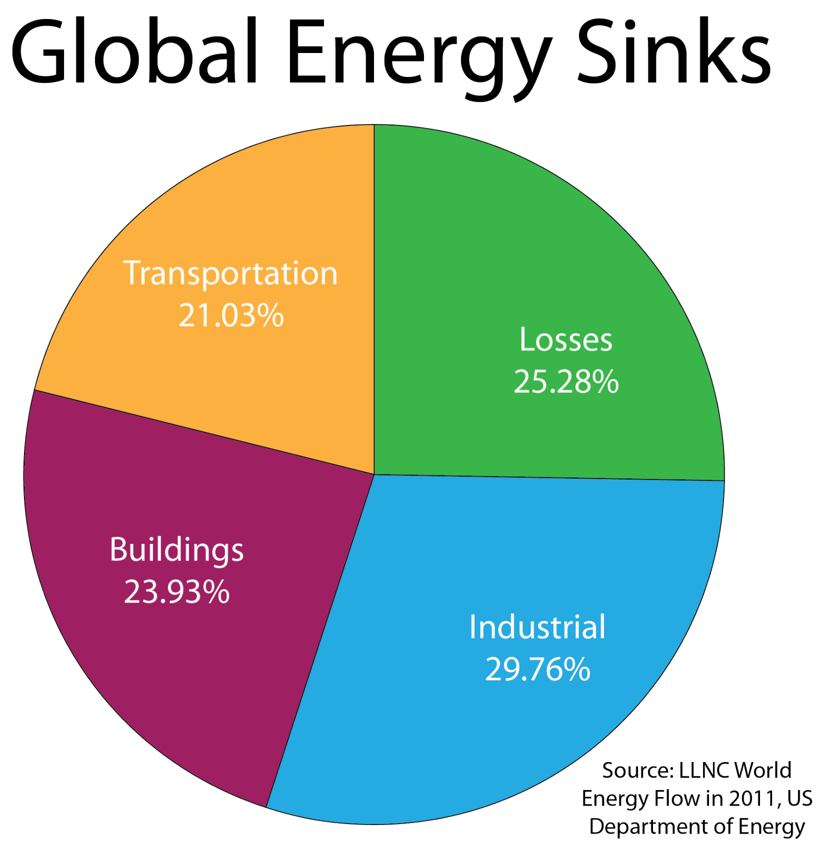

Figure 2. Global energy sinks, quantified on a percentage basis. The total of these sinks was 507 EJ.

Figures 1 and 2 give us a sense of where our energy comes from and how we use it.

1. What percent of energy ends up in the "losses" category? Why does this occur?

2. How much change would you expect could be made towards reducing these losses, and why?

3. What kinds of variations in this data do you think you would find for developed versus developing nations? (Make your own pie charts to answer this.)

4. What other questions do these graphs raise for you?

Global Energy Source to Sink

Units: Exajoules (EJ), or 1 X 10^{18} Joules

Wind	
Electricity	1.6
Total	1.6

Nuclear	
Electricity	28
Total	28

Hydro	
Electricity	13
Total	13

Biomass	
Electricity	4.6
Buildings	35.7
Industry	8.8
Transport	2.5
Total	51.6

Gas	
Electricity	47
Losses	2.2
Buildings	24.5
Industry	30
Transport	3.9
Total	107.6

Oil	
Electricity	13
Losses	11
Buildings	12.9
Industry	20
Transport	95
Total	151.9

Electricity	
Losses	130
Buildings	38.8
Industry	40.7
Transport	1.1
Total	210.6

Coal	
Electricity	100
Buildings	4.2
Industry	45
Total	149.2

Geothermal	
Electricity	2.4
Buildings	0.2
Total	2.6

Solar	
Electricity	0.25
Buildings	0.24
Industry	0.5
Total	0.99

Global Energy Sink to Source

Units: Exajoules (EJ), or 1 X 10^{18} Joules

Transport	
Electricity	1.1
Biomass	2.5
Gas	3.9
Oil	95
Total	102.5

Losses	
Electricity	130
Gas	2.2
Oil	11
Total	143.2

Electricity	
Wind	1.6
Geothermal	2.4
Solar	0.25
Hydro	13
Nuclear	28
Biomass	4.6
Coal	100
Gas	47
Oil	13
Total	209.85

Industry	
Electricity	40.7
Biomass	8.8
Coal	45
Gas	30
Oil	20
Solar	0.5
Total	145

Buildings	
Electricity	38.8
Biomass	35.7
Coal	4.2
Gas	24.5
Oil	12.9
Solar	0.24
Geothermal	0.275
Total	116.61

Data Source: LLNL 2014. Data is based on IEA's Extended World Energy Balances (2013 Edition). World Energy Flow in 2011. United States Department of Energy. https://flowcharts.llnl.gov/commodities/energy

Energy Flows: Connecting Sources and Sinks

Figures 3 and 4 take a significant step towards conveying the complexities of our current global energy system. They include the data from the previous two pie graphs and make connections showing how each energy source is used. This type of chart is called a *Sankey diagram*. Sources of energy are listed on the left, and end-uses and losses are listed on the right. Units are in Exajoules (1 x 10^{18} joules, EJ) per year. The horizontal and diagonal bars represent the flow of energy from sources to end-uses and losses. The widths of the energy-flow pathways correspond to the amounts of energy transferred. (Note: it takes approximately one joule of energy to throw an apple one meter up into the air).

Figure 3 focuses only on sources, sinks and connections for oil. 152 Exajoules of oil were used in 2011. The oil was used for transport, industry, buildings and electricity. A significant portion of usable energy was lost during transformation as well. Based on the width of each connection, you can see that more than half of the energy in oil went to transport.

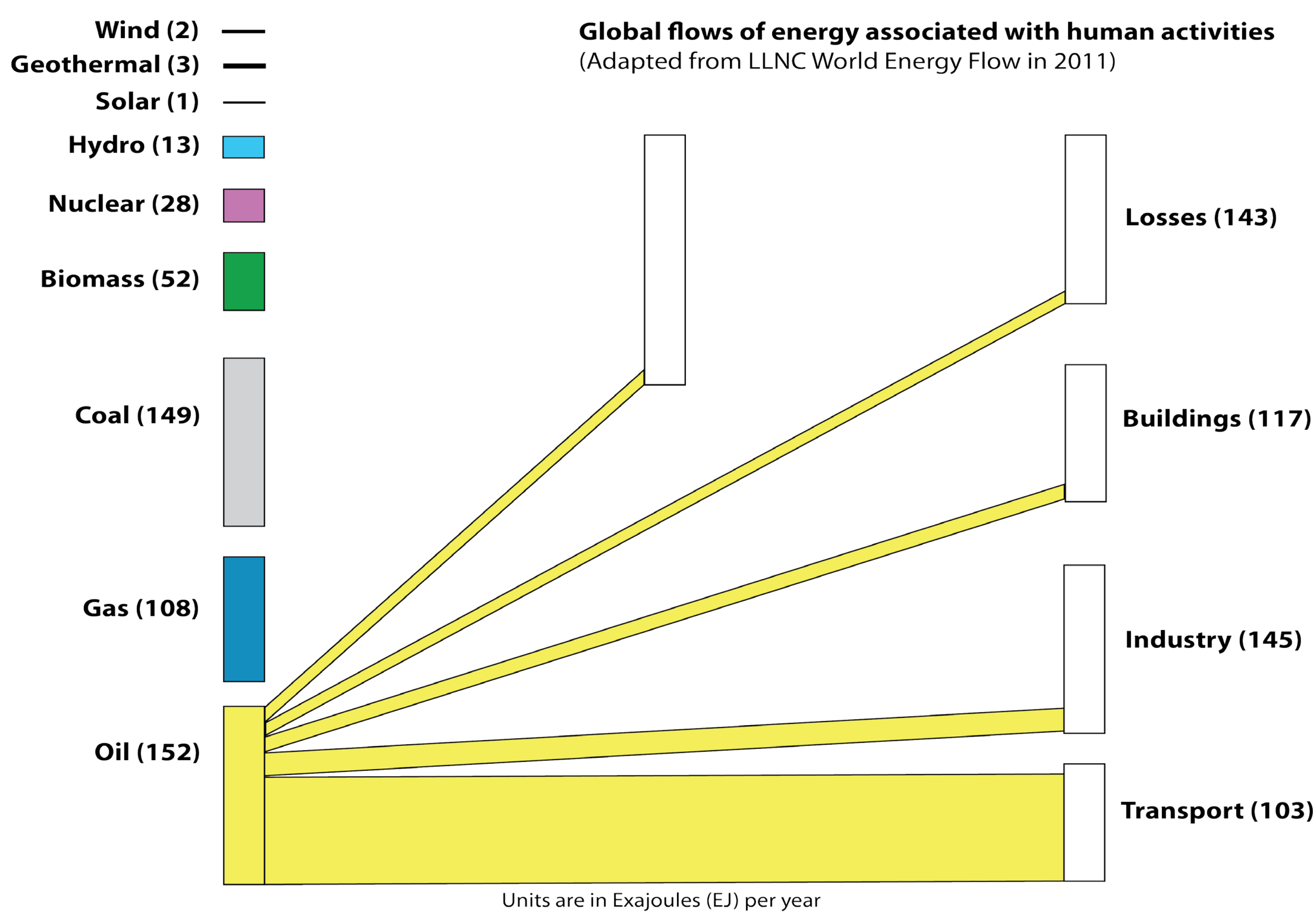

Figure 3. Global energy flows for oil. Sankey diagram showing energy sources and sinks for oil. Numbers associated with end-uses are totals from all energy sources, not just oil.

Figure 4 fills in the rest of the connections between sources and sinks. Take some time to consider the patterns. How is each energy source used? What are the energy source(s) for each end-use? Are there some end-uses that depend on only one energy source? What do you find surprising or unexpected? After coming up with your own questions and hypothetical explanations answer the discussion questions that follow.

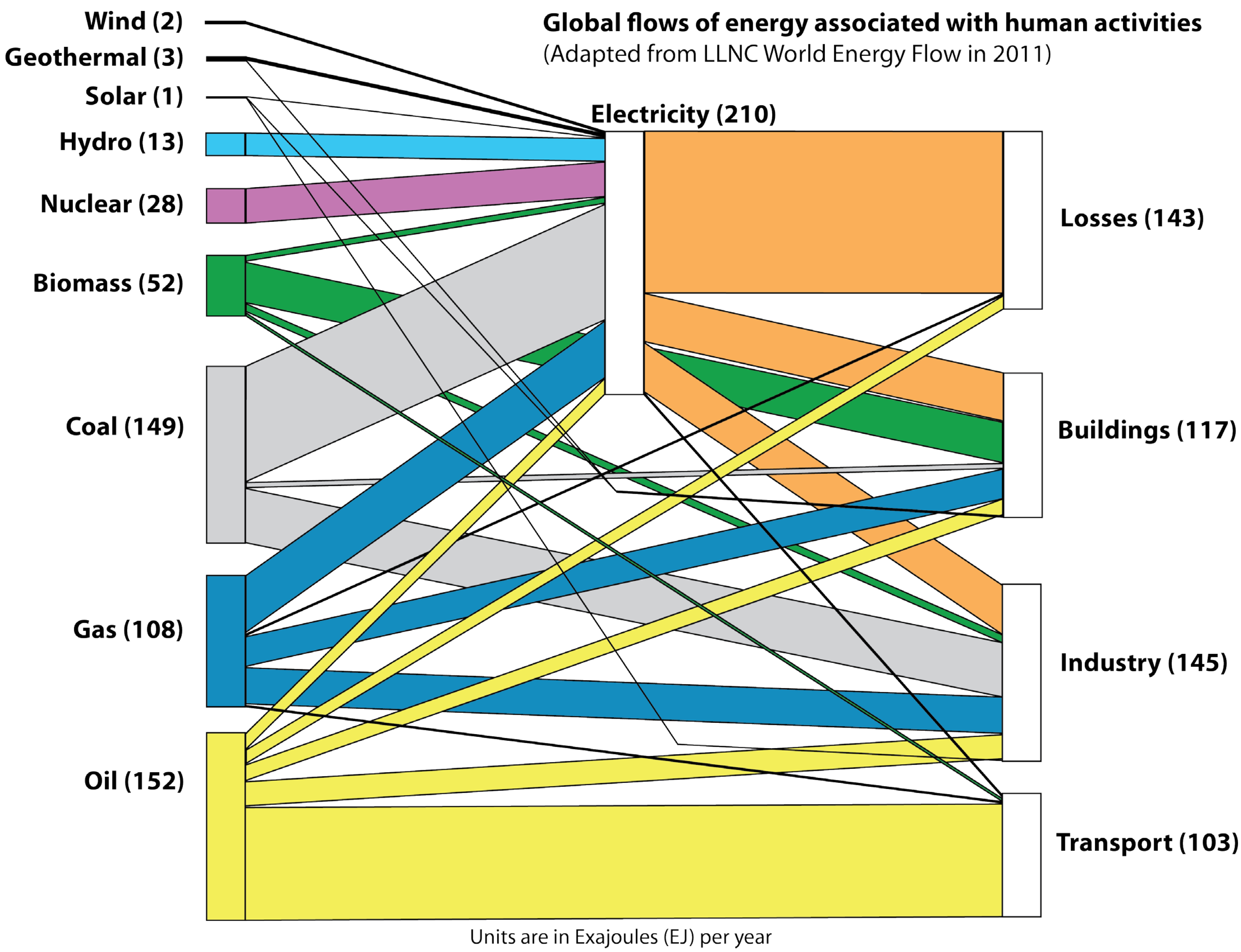

Figure 4. Global energy flows. Sankey diagram showing all energy sources, sinks and connections between them.

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Discussion Questions for Figure 4

1. Why does the vast majority of energy for transportation come from oil, while the energy for industry and buildings comes from a number of different sources?

2. Why is electricity used given that there is such a large quantity of lost energy associated with its production and consumption?

3. Nuclear energy is largely used to generate electricity. Why?

4. Which of the energy sources are strongly associated with the emission of greenhouse gases? Given your answer to this question, how would you rank the end-uses on the right in terms of the difficulty to reduce these emissions? Explain your ranking.

5. Biomass use currently accounts for about 10% of energy flow. On a global basis where (geographically, socio-politically, etc) do you think most of this use is located, and why?

6. Research and development is currently underway to greatly expand the use of biomass for the production of ethanol and other fuels as an alternative to petroleum-based transportation fuels. How would this change this diagram, and what would the potential opportunities and challenges be for this change?

7. What other questions do you have regarding the data in this graph?

Even greater levels of detail can be shown for the energy flows. Figure 5 shows a higher resolution of information on bioenergy sources, end-uses and corresponding pathways.

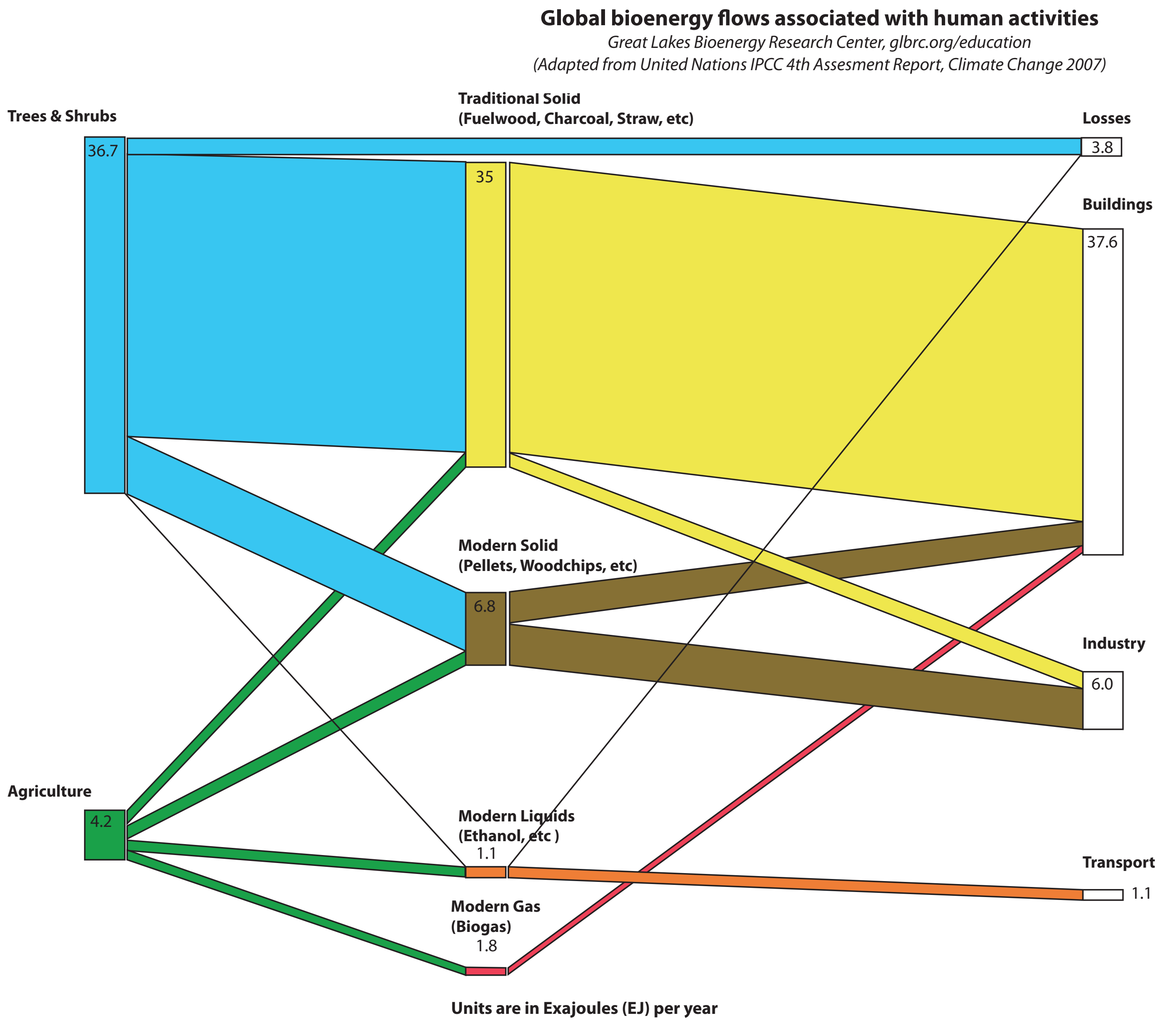

Figure 5. Global bioenergy flows. Sources of energy are listed on the left, and end-uses and losses are listed on the right.

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Discussion Questions for Figure 5

1. On a relative basis, there is much less biomass energy associated with losses than for the total global energy system (Figure 4). Why do you think this is?

2. How would you expect the proportions of sources to change if there was a significant increase in bioenergy used for transport?

3. How would you expect the relative amount of losses to change if there was a significant increase in biofuels used for transport, and why?

4. Develop one or more of your own questions.

Global Biomass Energy Source to Sink

Units: Exajoules (EJ), or 1 X 10^{18} Joules

Trees & Shrubs	
Losses	1.7
Traditional Solid	31.3
Modern Solid	3.1
Modern Liquids	0.6
Total	36.7

Agriculture	
Traditional Solid	2.0
Modern Solid	0.9
Modern Liquids	0.5
Modern Gas	0.8
Total	4.2

Traditional Solid	
Buildings	33.0
Industry	2.0
Total	35.0

Modern Liquids	
Losses	0.1
Industry	0.1
Transport	0.9
Total	1.1

Modern Solid	
Buildings	2.8
Industry	4.0
Total	6.8

Modern Gas	
Buildings	1.8
Total	1.8

Global Biomass Energy Sink to Source

Units: Exajoules (EJ), or 1 X 10^{18} Joules

Losses	
Trees & Shrubs	1.7
Modern Liquids	2.1
Total	3.8

Industry	
Traditional Solid	2.0
Modern Solid	4.0
Total	6.0

Buildings	
Traditional Solid	33.0
Modern Solid	2.8
Modern Gas	1.8
Total	37.6

Transport	
Modern Liquid	1.1
Total	1.1

Data Source: Metz et al. 2007. Climate Change 2007: Mitigation of Climate Change, UN IPCC 4th Report, Working Group III. Cambridge University Press. *http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch4s4-3-3-3.html*