

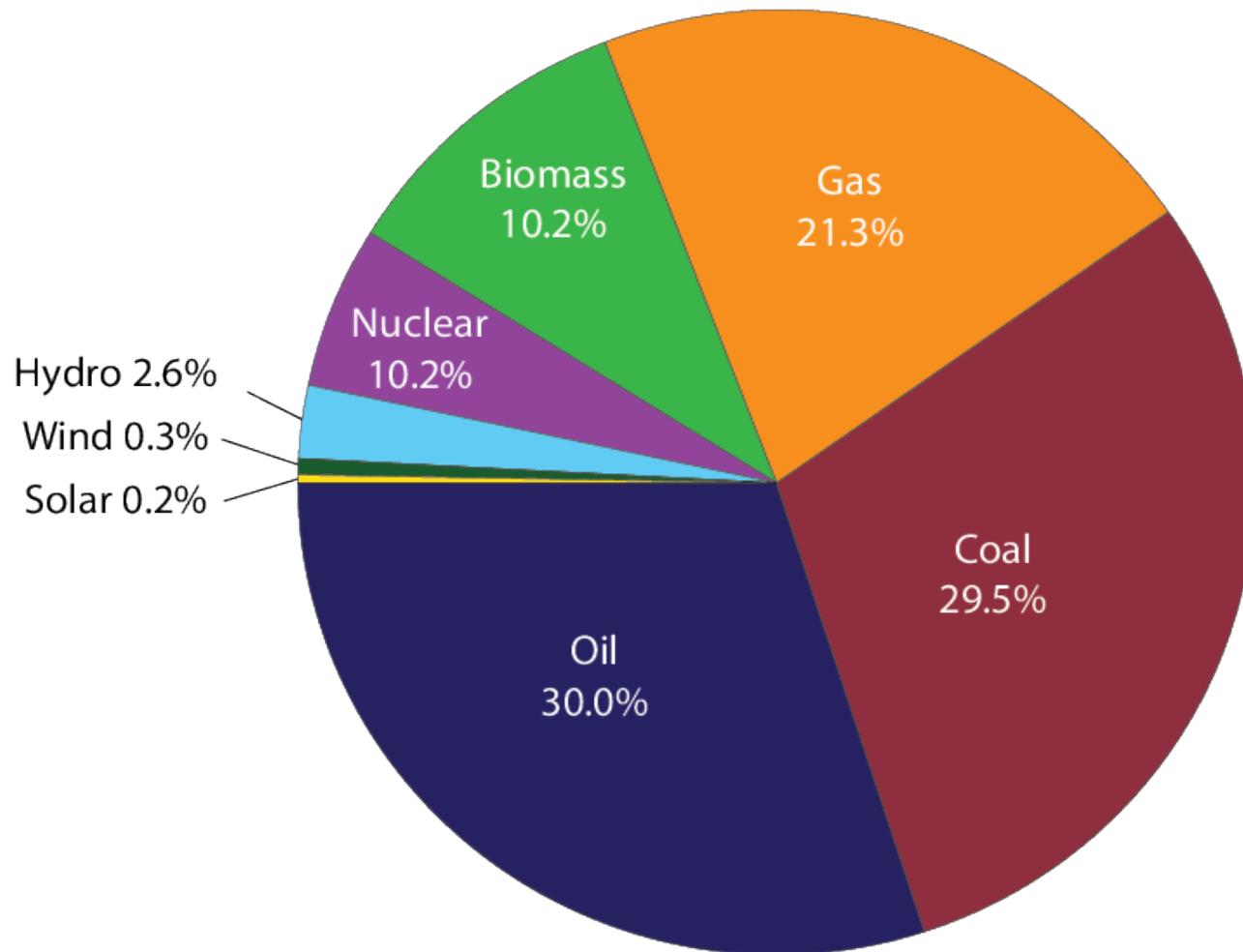


Global Energy Flows and Bioenergy: A Systems Thinking Problem Space

Global Energy Flows

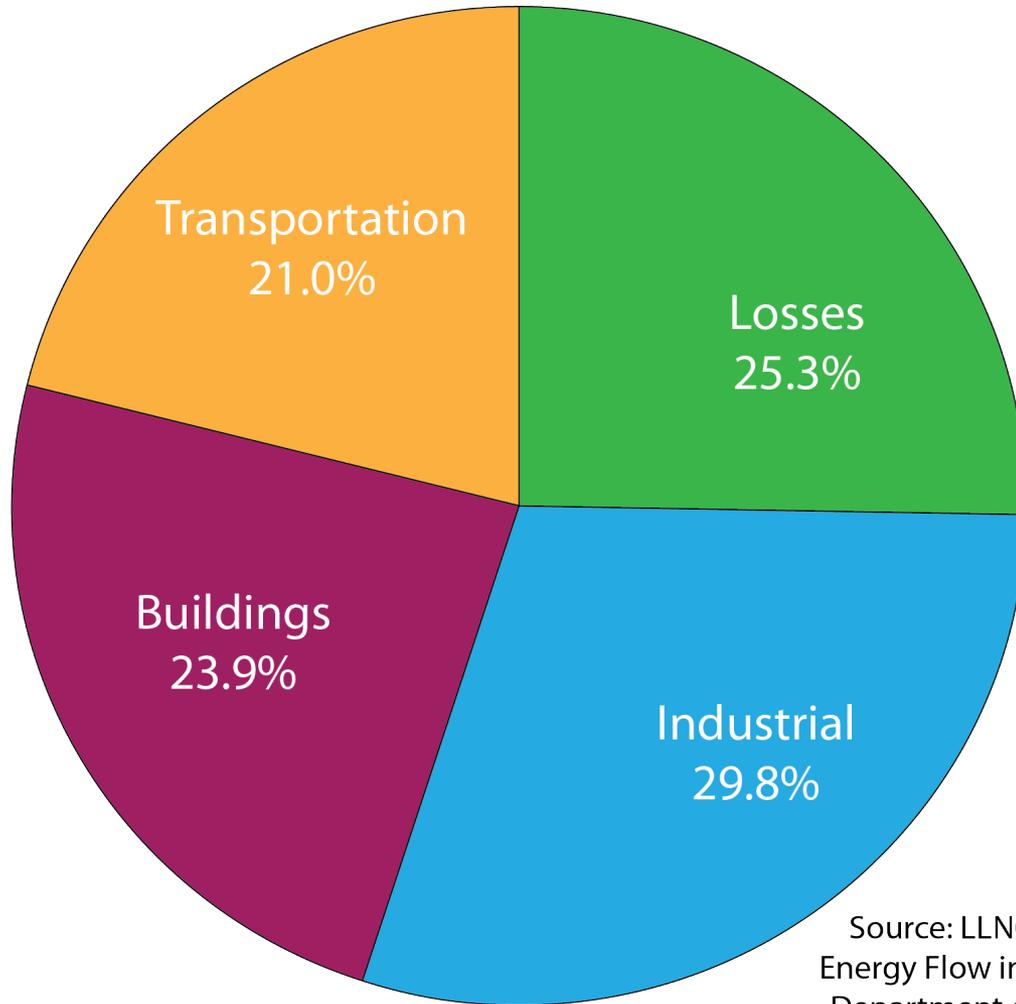
- ✧ Where do we get our energy?
 - (What are our sources?)
- ✧ How do we use it?
 - (What are our sinks?)
- ✧ What are the energy flows from these sources to these sinks?
- ✧ Bioenergy?

Global Energy Sources



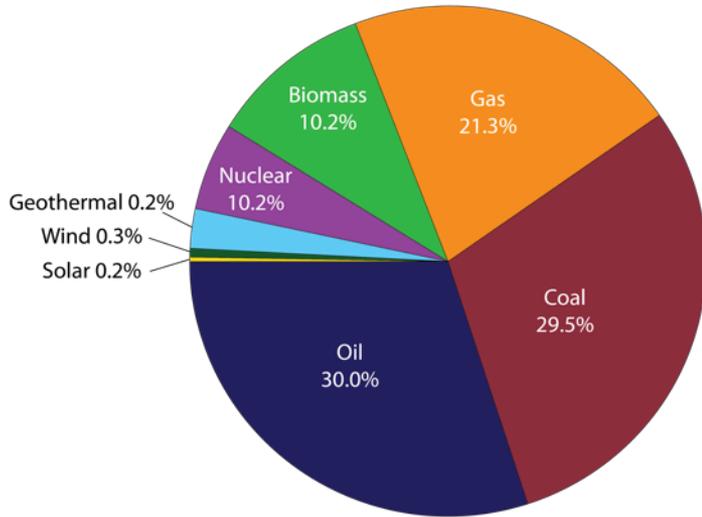
Source: LLNC World
Energy Flow in 2011, US
Department of Energy

Global Energy Sinks



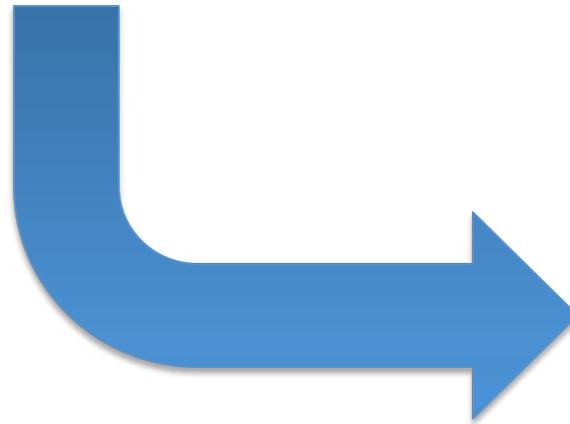
Source: LLNC World Energy Flow in 2011, US Department of Energy

Global Energy Sources

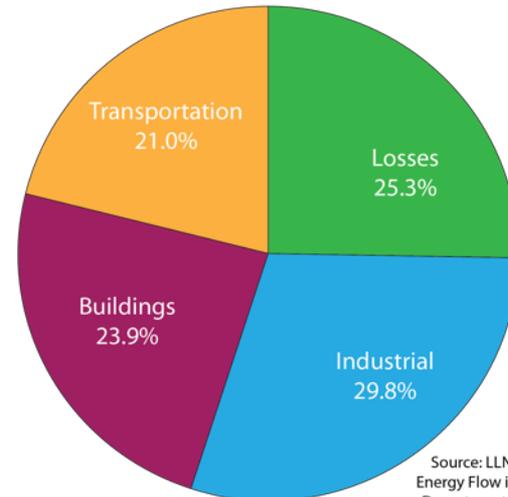


Source: LLNC World Energy Flow in 2011, US Department of Energy

How do we get from source to sinks?



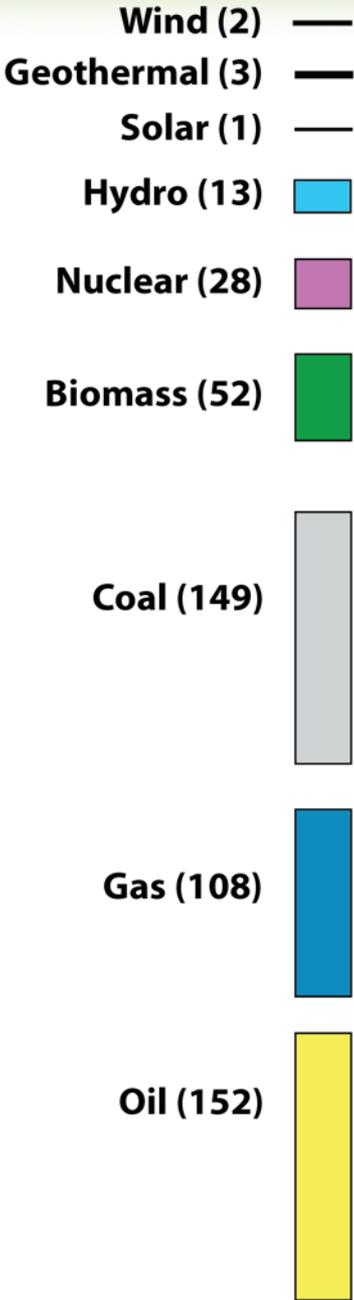
Global Energy Sinks



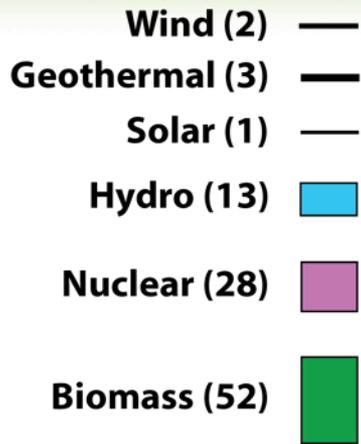
Source: LLNC World Energy Flow in 2011, US Department of Energy

Global flows of energy associated with human activities

(Adapted from LLNC World Energy Flow in 2011)

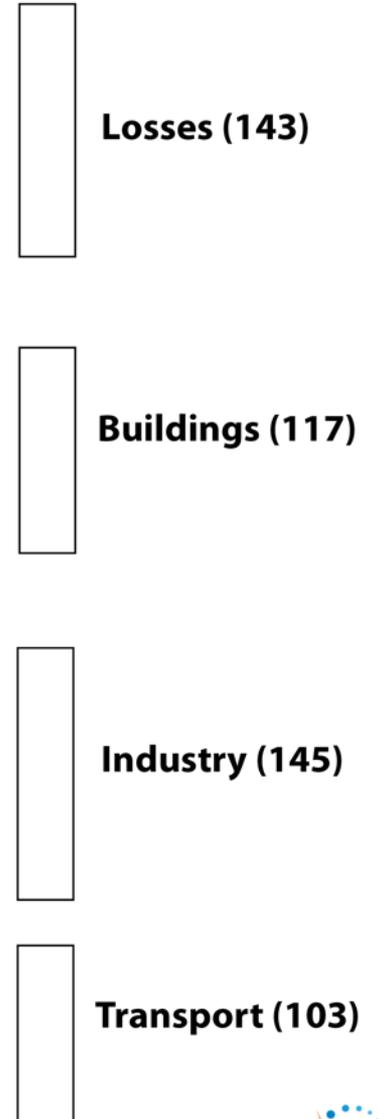
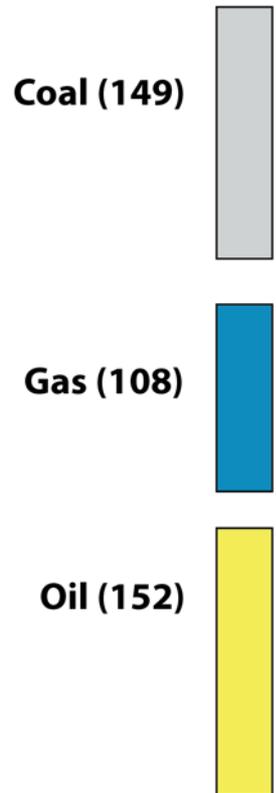


Units are in Exajoules (EJ) per year

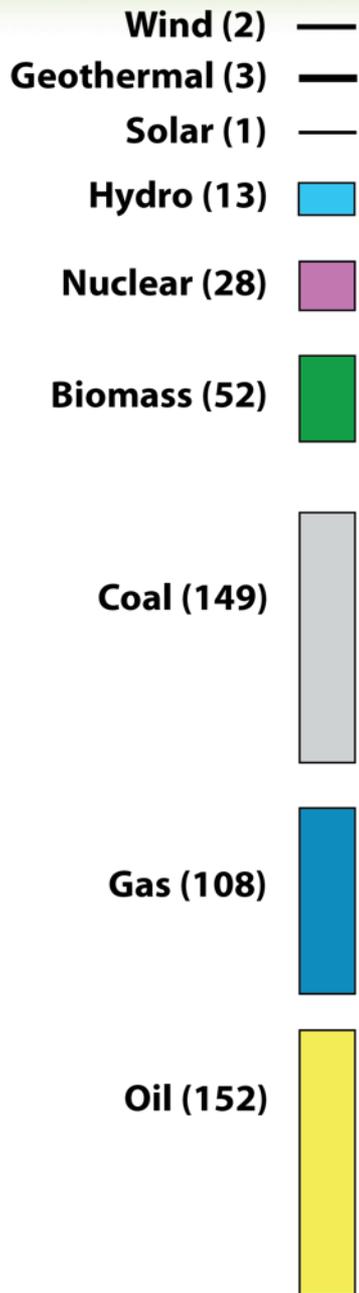


Global flows of energy associated with human activities

(Adapted from LLNC World Energy Flow in 2011)



Units are in Exajoules (EJ) per year



Global flows of energy associated with human activities

(Adapted from LLNC World Energy Flow in 2011)

Electricity (210)



Losses (143)



Buildings (117)



Industry (145)



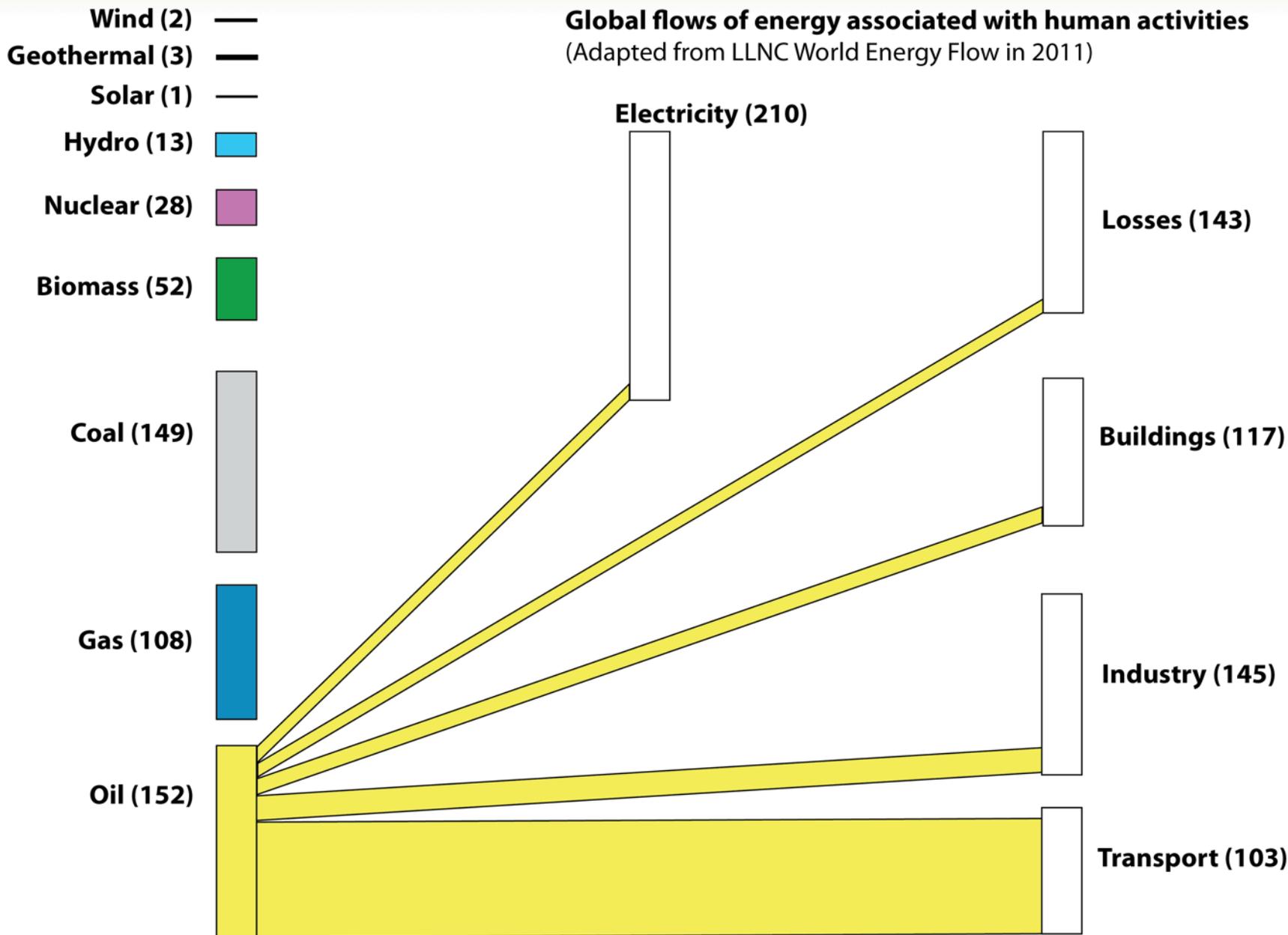
Transport (103)



Units are in Exajoules (EJ) per year

Global flows of energy associated with human activities

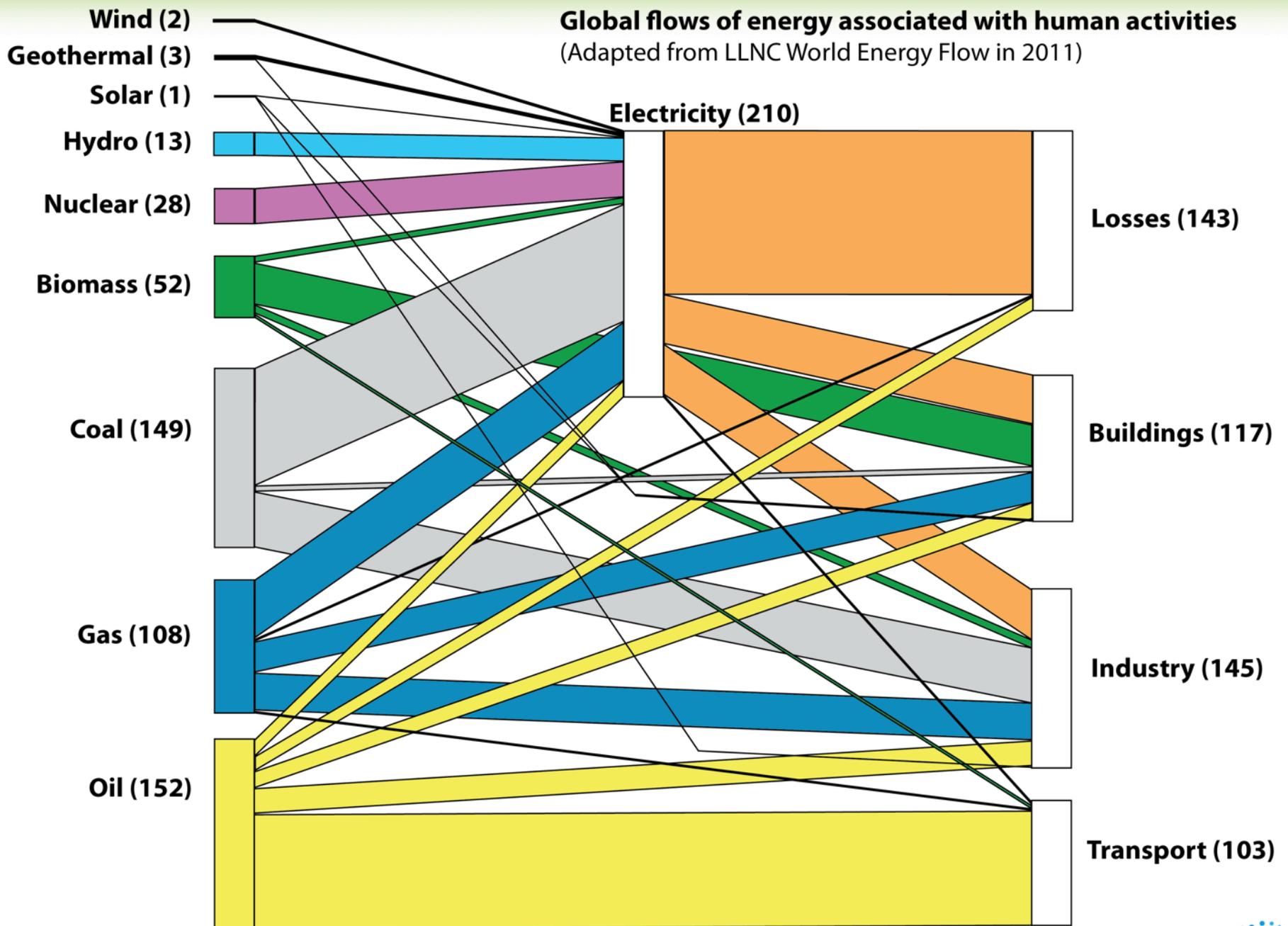
(Adapted from LLNC World Energy Flow in 2011)



Units are in Exajoules (EJ) per year

Global flows of energy associated with human activities

(Adapted from LLNC World Energy Flow in 2011)

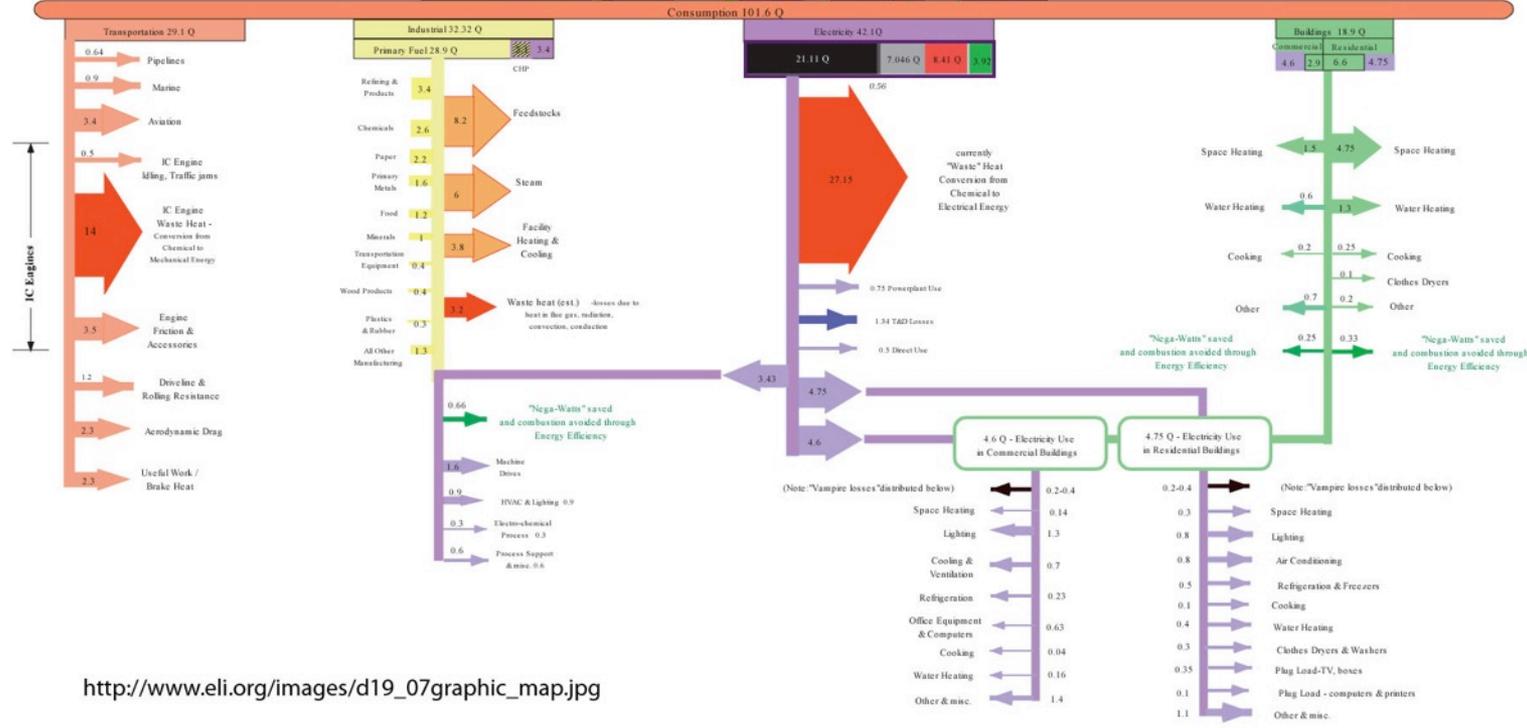
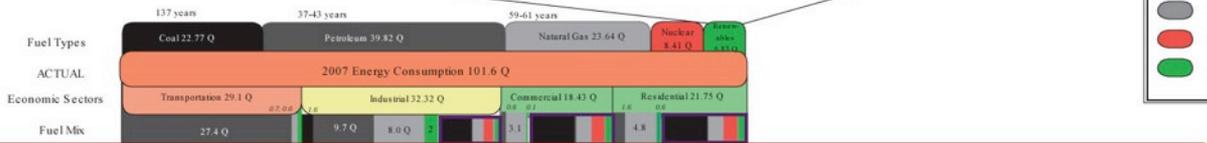
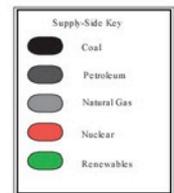
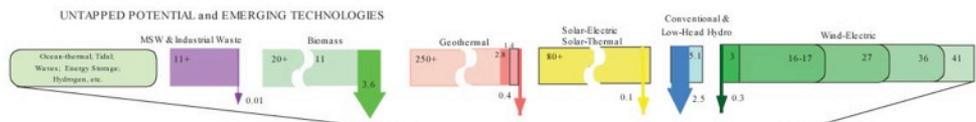
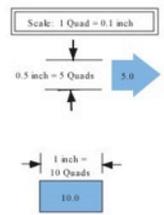


Units are in Exajoules (EJ) per year

Energy Flows in the United States - 2007

in Quadrillion British Thermal Units (Quads or 10¹⁵ Btu)

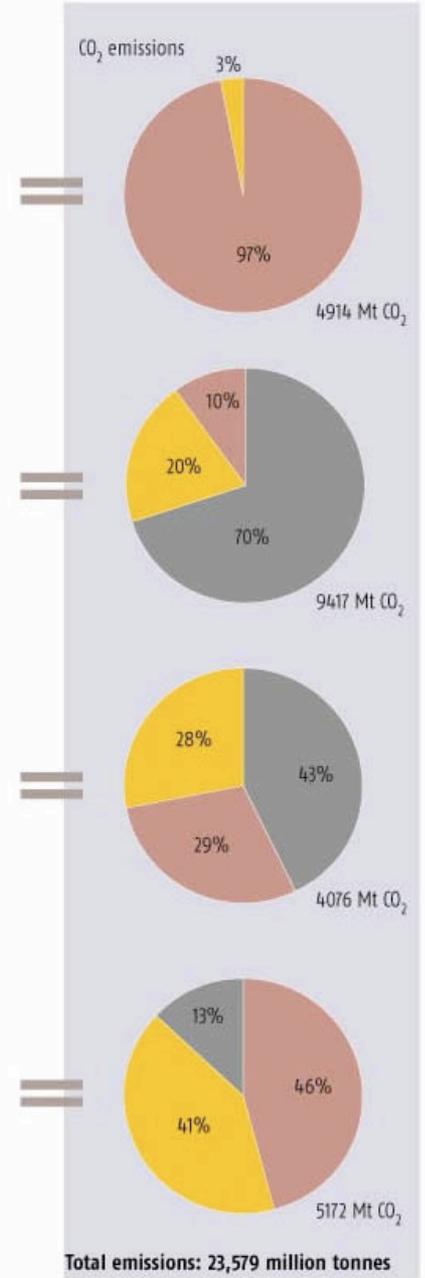
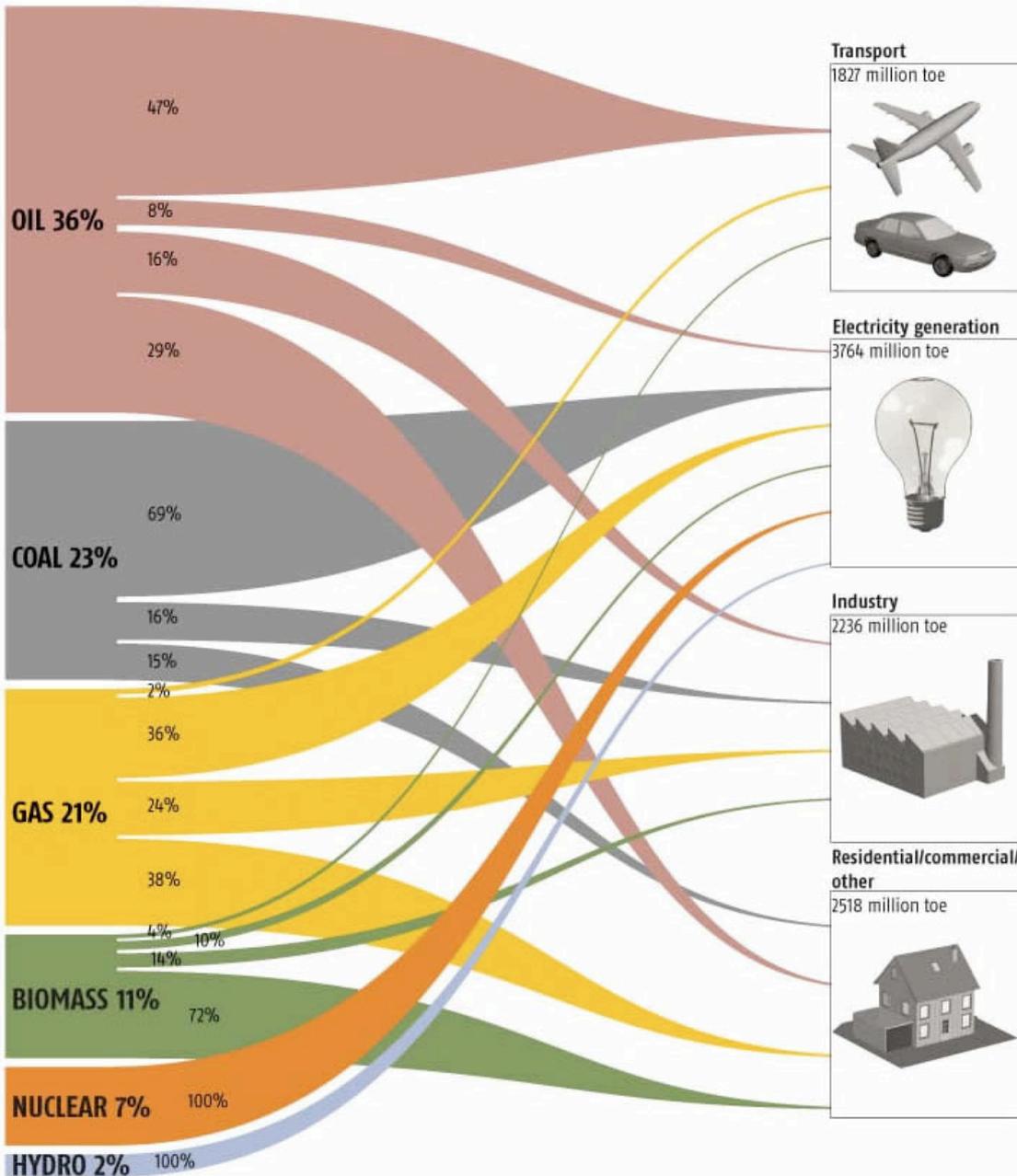
Created by David A. Bassett
Funded by David Rejeski
Woodrow Wilson International Center &
The Environmental Law Institute



http://www.eli.org/images/d19_07graphic_map.jpg

GLOBAL ANNUAL ENERGY USE

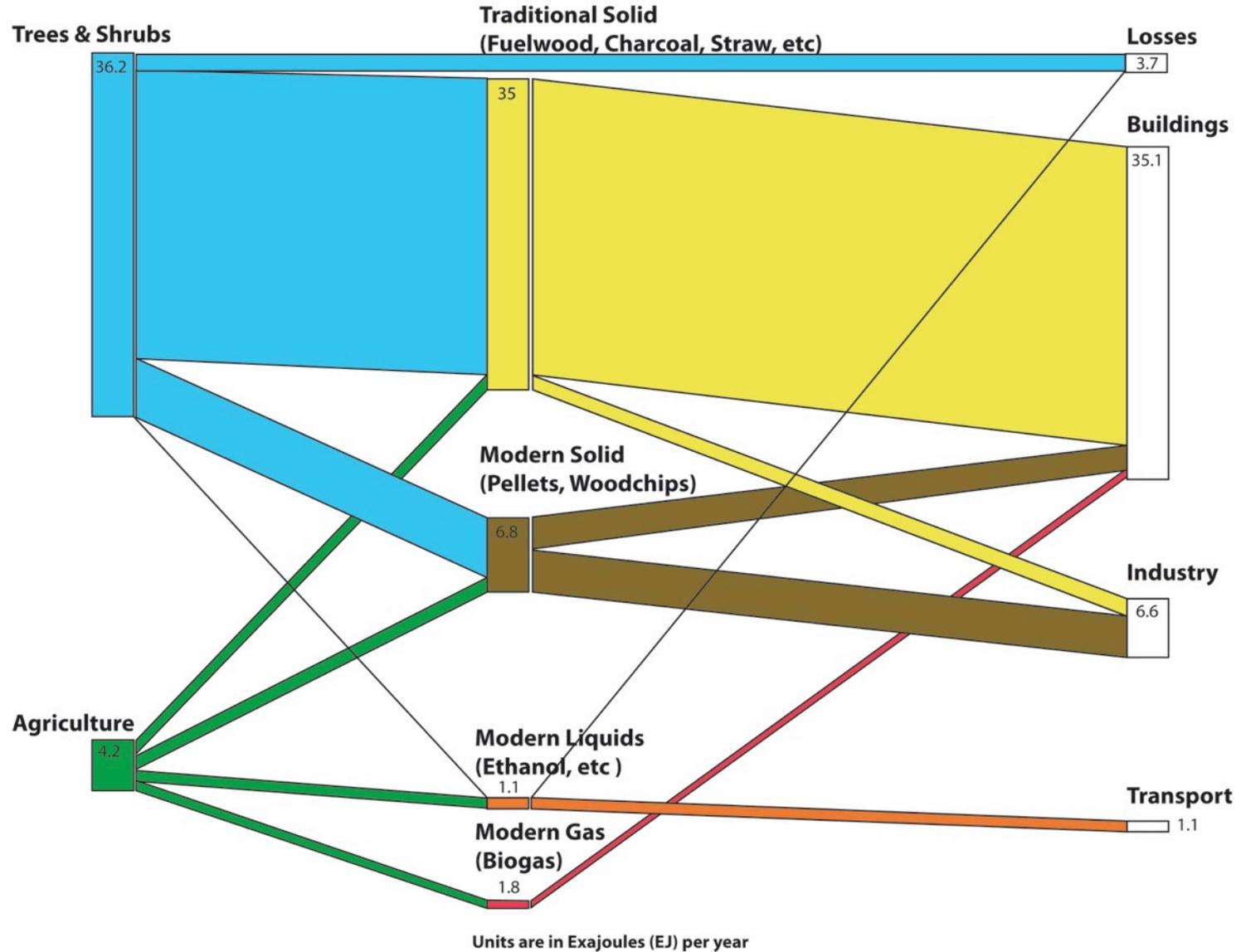
10,345 million tonnes oil equivalent



Global biomass flows of energy associated with human activities

Great Lakes Bioenergy Research Center, glbrc.org/education

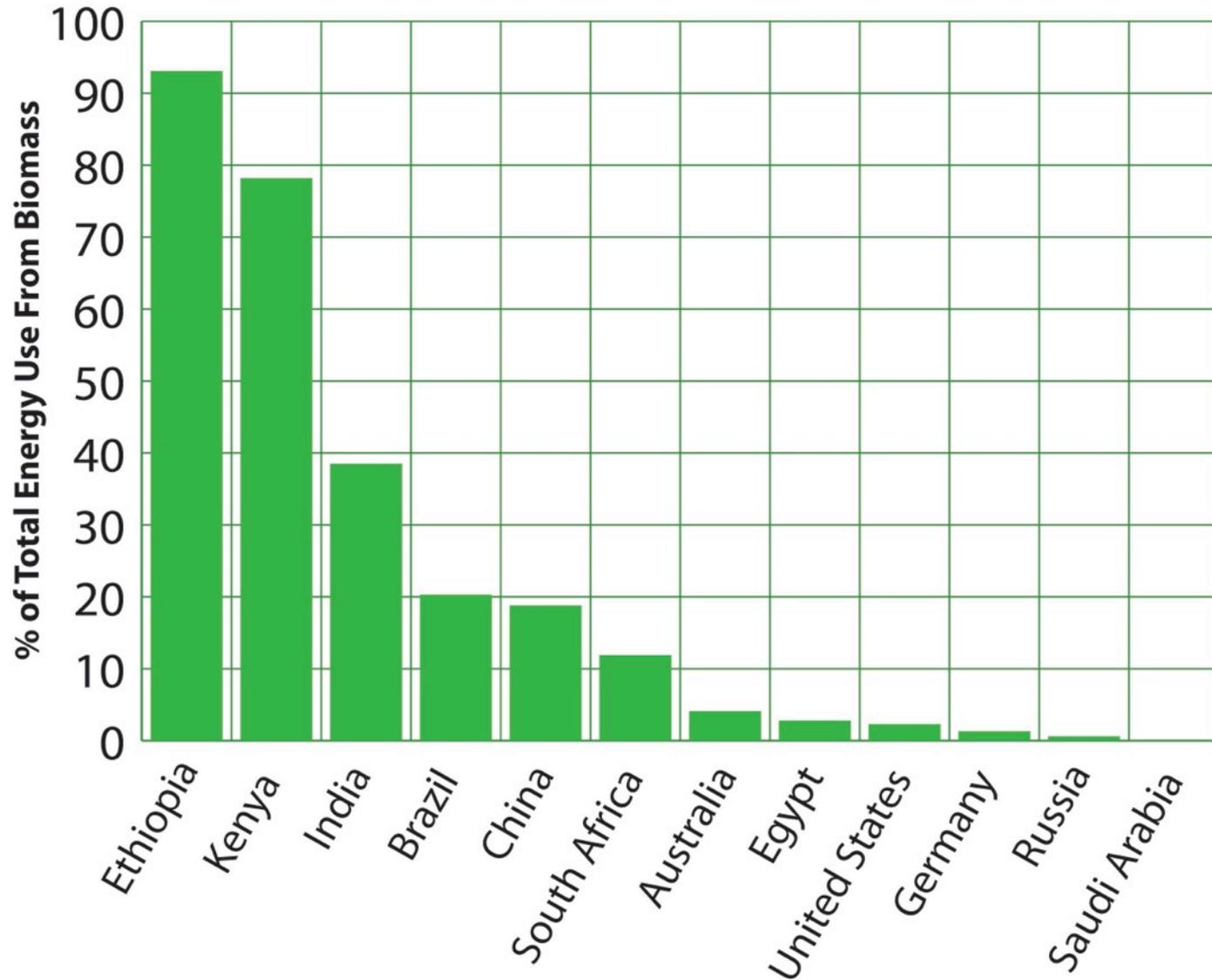
(Adapted from United Nations IPCC 4th Assessment Report, Climate Change 2007)



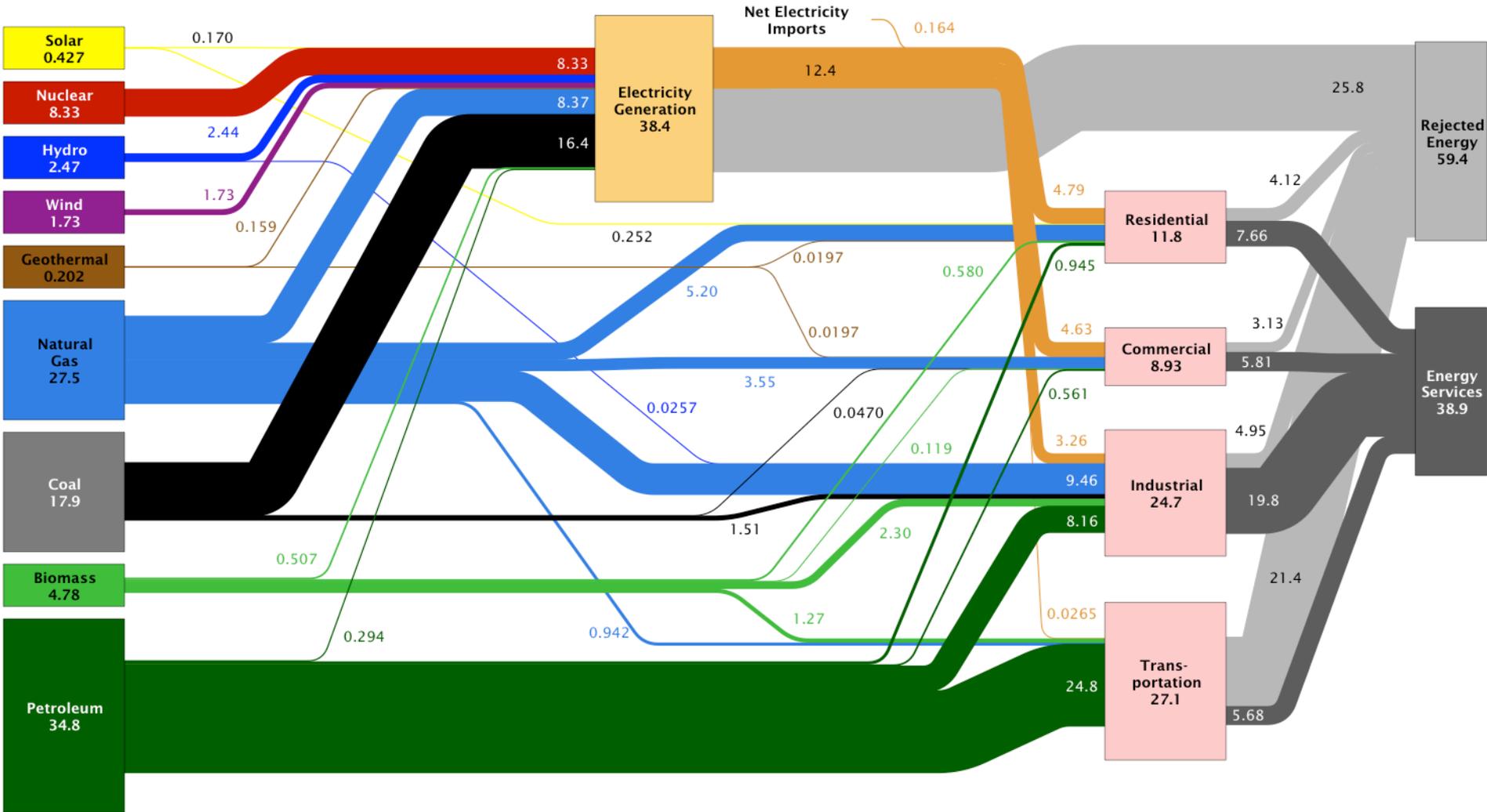
Units are in Exajoules (EJ) per year

Biomass Energy Use by Country

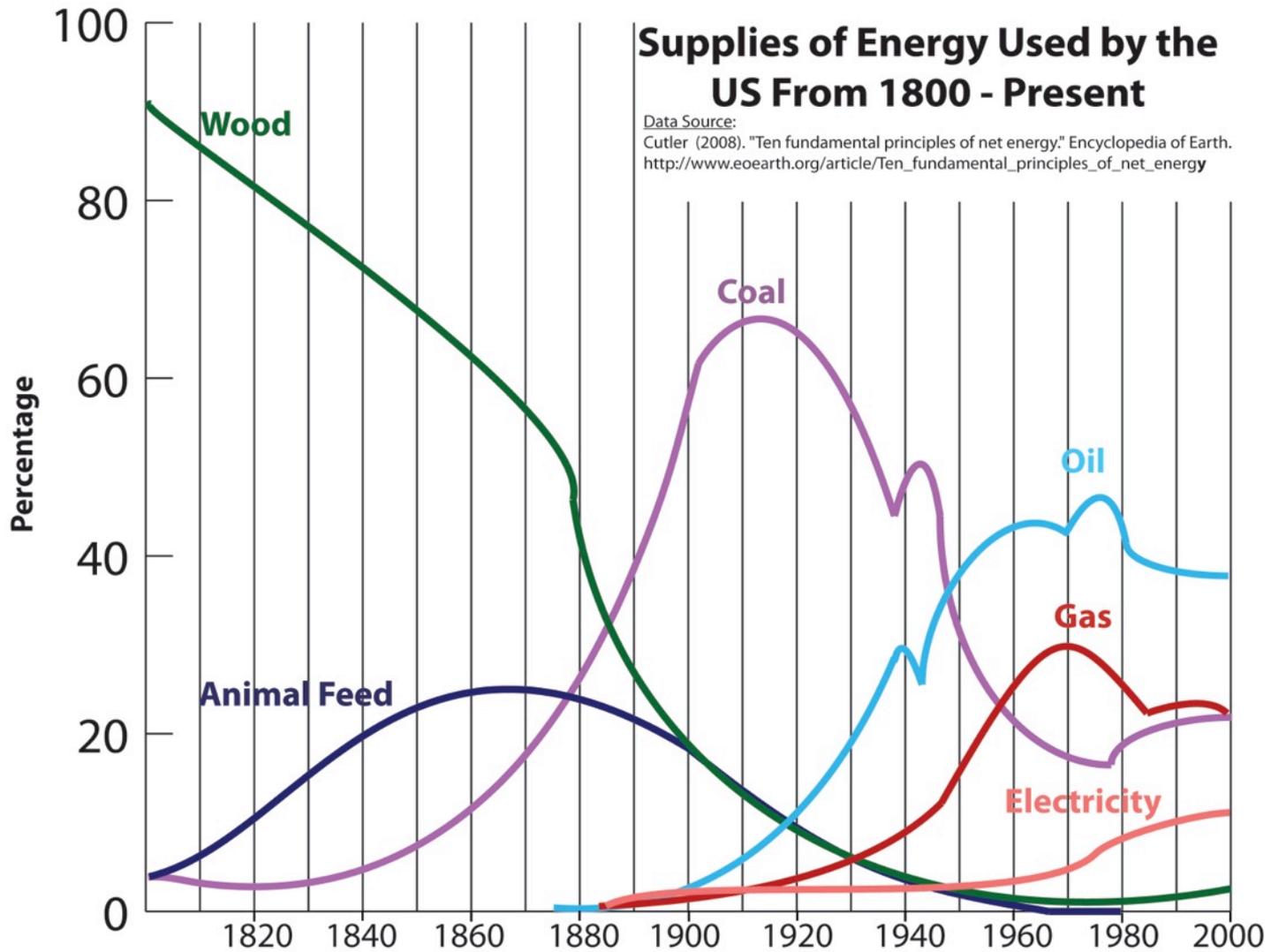
Source Data: Earth Trends Data Tables: Energy Consumption by Source, 2005.
<http://earthtrends.wri.org/datatables/index.php?theme=6>



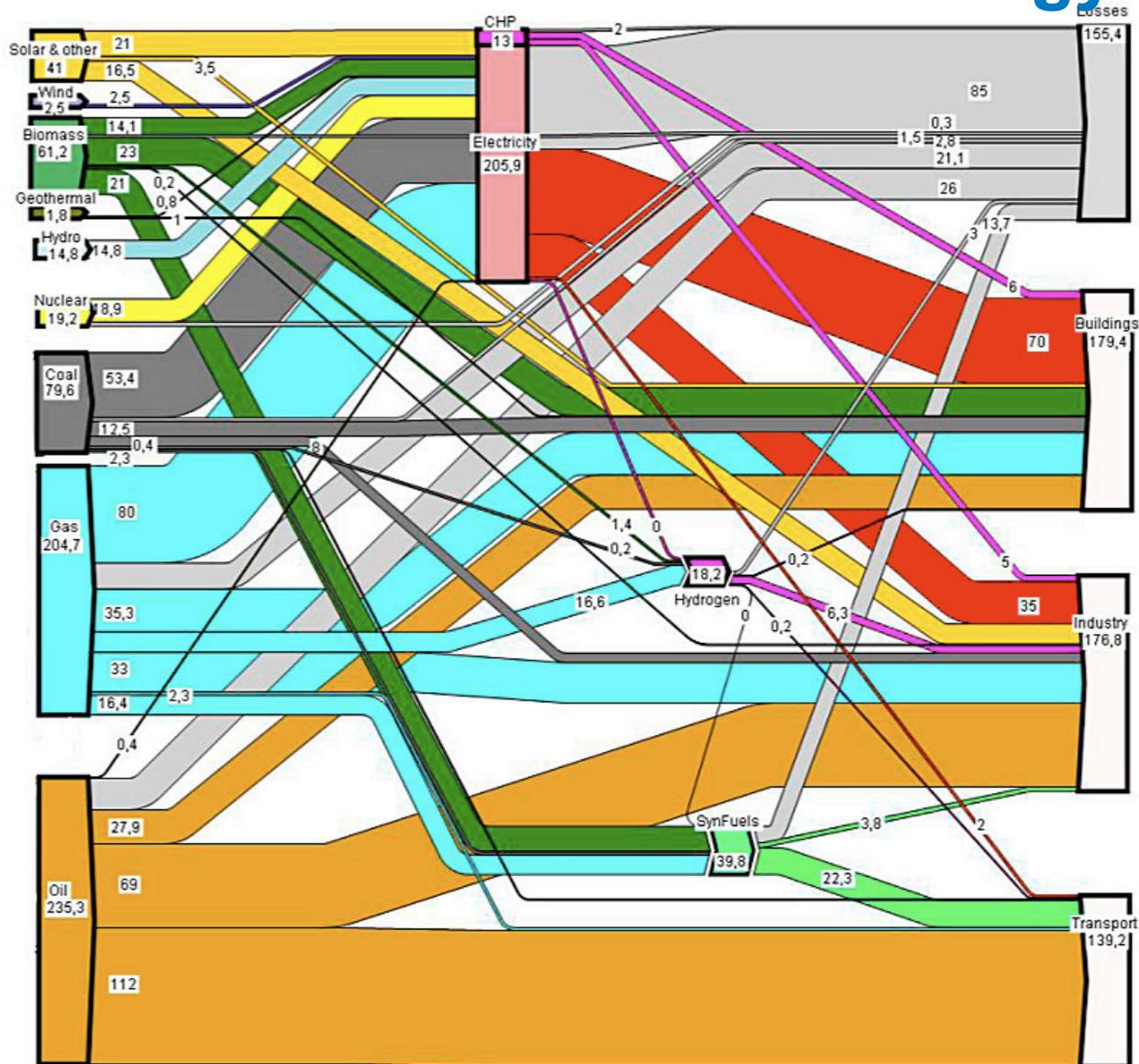
Estimated U.S. Energy Use in 2014: ~98.3 Quads



Source: LLNL 2015. Data is based on DOE/EIA-0035(2015-03), March, 2014. 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



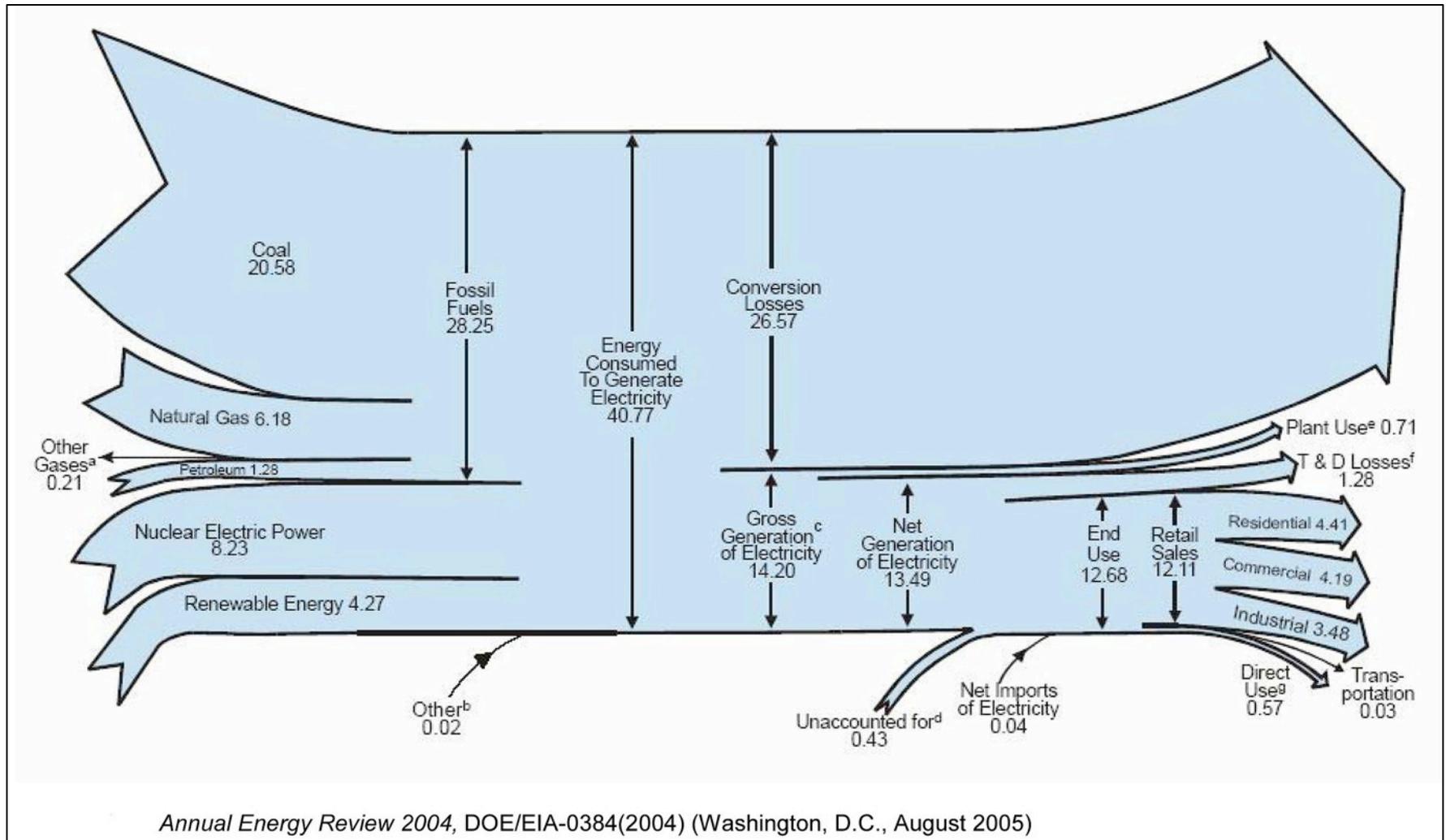
2030 IPCC "Predicted" Global Energy Flows



U.N. IPCC 4th Assessment Report, Working Group III, 2007

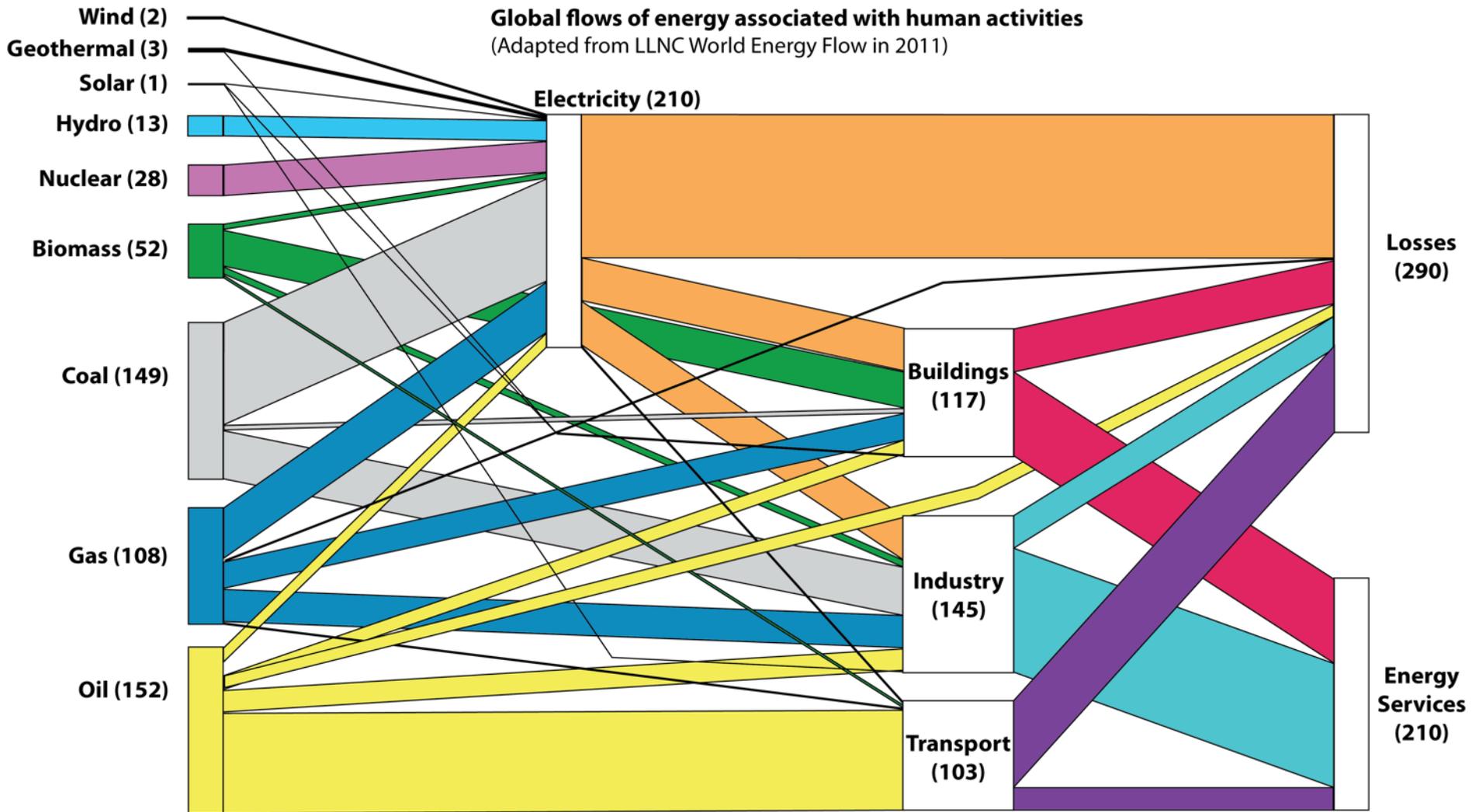
Supplementary Slides

U.S. Electrical Energy Flow



Global flows of energy associated with human activities

(Adapted from LLNC World Energy Flow in 2011)



Units are in Exajoules (EJ) per year

Napoleon's 1812 – 1813 March on Russia Sankey Diagram

Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.

Dessiné par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite Paris, le 20 Novembre 1869.

Les nombres d'hommes présents sont représentés par les largeurs des zones colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en lettres de ces zones. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M. M. Chiers, de Léger, de Fezensac, de Chambray et le journal inédit de Jacob, pharmacien de l'Armée depuis le 28 Octobre. Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davout, qui avoient été détachés sur Minsk et Mohilow et en rejoigni vers Orscha et Witebsk, avoient toujours marché avec l'armée.

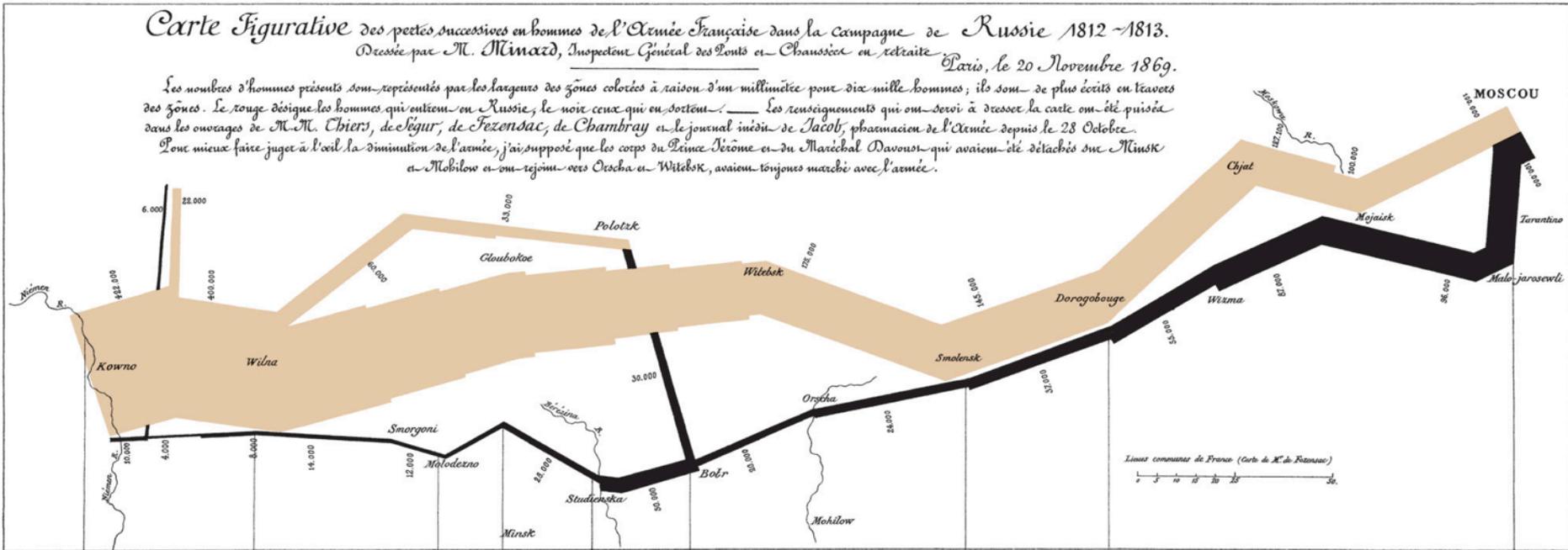
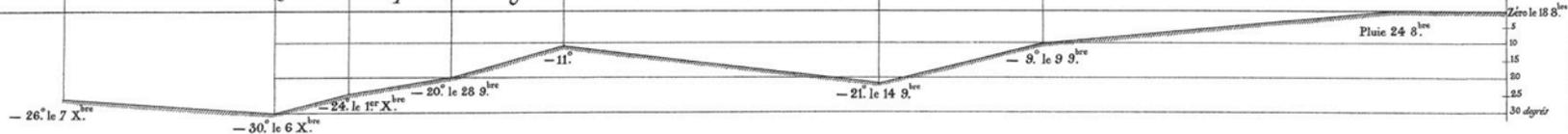


TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.



Wikipedia "Commons" <http://upload.wikimedia.org/wikipedia/commons/2/29/Minard.png>

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May 2011



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