Energy In Ecosystems

• Interpret diagrams and data related to energy flow in individuals, populations and ecosystems.
• Define, describe and calculate different types of energy efficiencies.
• Contrast efficiencies of various groups of organisms
• Interpret and explain pyramids of energy, biomass and numbers.
• Distinguish net primary productivity and gross primary productivity.
• Interpret patterns of primary productivity in aquatic and terrestrial ecosystems.
• Apply energy concepts to problems such as population biology, conserving rare species, bioaccumulation, and human impacts on the environment.
ENERGY FLOW THROUGH THE INDIVIDUAL

- B = Biomass
- C = consumption
- A = Assimilation
- FU = Rejects
- R = Respiration
- G = Growth
- L = Lost biomass
- P = Production
- dB = change in Biomass

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ENERGY FLOW THROUGH THE POPULATION

- **B** = Biomass
- **C** = consumption
- **A** = Assimilation
- **FU** = Rejects
- **R** = Respiration
- **G** = Growth
- **L** = Lost biomass
- **P** = Production
- **dB** = change in Biomass
- **E** = Energy lost to ecosystem

\[ P = E + \Delta B \]
Exploitation efficiency = food ingested divided by the amount of prey production ($I / P_{n-1}$)

Assimilation efficiency = assimilation divided by the amount of food ingestion ($A / I$)

Net Production efficiency = consumer production divided by the amount of assimilation ($P_n / A$)
• **Gross Production efficiency** = assimilation efficiency multiplied by the net production efficiency = consumer production divided by amount of ingestion \((P_n / I)\)

• **Ecological efficiency** = (exploitation efficiency) \(\times\) (assimilation efficiency) \(\times\) (net production efficiency) which is equivalent to consumer production divided by the amount of prey production \((P_n / P_{n-1})\)
Producers 97,000 kJ

Primary consumer 7000 kJ

Secondary consumer 600 kJ

Tertiary Consumer 50 kJ

Pyramid of Numbers  
Fox  
Rabbit  
Grass

Pyramid of Biomass  
Sea Lion  
Herring  
Zooplankton  
Phytoplankton

Pyramid of Energy

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NPP gC/m*m*yr from Cramer et al 2001
Figure 4. The estimated NPP for the coterminous United States
Global Primary Productivity

- **solar constant** = $1.05 \times 10^{10}$ cal m$^{-2}$ yr$^{-1}$
- Global Plant GPP = $5.83 \times 10^6$ cal m$^{-2}$ yr$^{-1}$
  (0.06% of the amount of solar constant)
- Global Plant NPP = $4.95 \times 10^6$ cal m$^{-2}$ yr$^{-1}$
  (0.05% of the solar constant)
- Maximum efficiency = 2-3%
Howard Odum – Silver Springs
Percent of NPP appropriated by humans
Global carbon flows related to the human appropriation of net primary production (HANPP) around the year 2000

<table>
<thead>
<tr>
<th>NPP-related carbon flows</th>
<th>Total NPP</th>
<th></th>
<th>Aboveground NPP</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pg C/yr</td>
<td>%</td>
<td>Pg C/yr</td>
<td>%</td>
</tr>
<tr>
<td>Potential vegetation (NPP₀)</td>
<td>65.51</td>
<td>100</td>
<td>35.38</td>
<td>100</td>
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<tr>
<td>Actual vegetation (NPPₐₓₜ)</td>
<td>59.22</td>
<td>90.4</td>
<td>33.54</td>
<td>94.8</td>
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<tr>
<td>Human-induced alteration of NPP (ΔNPPₗₗₜ)</td>
<td>6.29</td>
<td>9.6</td>
<td>1.84</td>
<td>5.2</td>
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<tr>
<td>Human harvest (NPPₕ)</td>
<td>8.18</td>
<td>12.5</td>
<td>7.22</td>
<td>20.4</td>
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<tr>
<td>Human-induced fires</td>
<td>1.14</td>
<td>1.7</td>
<td>1.14</td>
<td>3.2</td>
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<tr>
<td>Remaining in ecosystem (NPPₜ)</td>
<td>49.9</td>
<td>76.2</td>
<td>25.18</td>
<td>71.2</td>
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<tr>
<td>HANPPₜₗₜₚ total</td>
<td>15.6</td>
<td>23.8</td>
<td>10.2</td>
<td>28.8</td>
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<td>Backflows to nature*</td>
<td>2.46</td>
<td>3.7</td>
<td>1.5</td>
<td>4.2</td>
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<tr>
<td>Concentration found in:</td>
<td>Concentration of DDT in parts per million:</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>-------------------------</td>
<td>------------------------------------------</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Water</td>
<td>0.00005</td>
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<td>Plankton</td>
<td>0.04</td>
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<tr>
<td>Sheepshead minnow</td>
<td>0.94</td>
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<tr>
<td>Pickeral</td>
<td>1.33</td>
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<tr>
<td>Atlantic needlefish</td>
<td>2.07</td>
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<tr>
<td>Merganser</td>
<td>22.8</td>
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<td>Cormorant</td>
<td>26.4</td>
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<tr>
<td>Animal product</td>
<td>How many pounds of feed required to produce</td>
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<td></td>
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<td>----------------</td>
<td>-------------------------------------------</td>
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<tr>
<td>1 lb of Talapia</td>
<td>1.7 lbs of feed</td>
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<tr>
<td>1 lb of Chicken</td>
<td>2.4 lbs of feed</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1 lb of Rabbit</td>
<td>3.0 lbs of feed</td>
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<td></td>
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<tr>
<td>1 lb of Eggs</td>
<td>4.6 lbs of feed</td>
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<tr>
<td>1 lb of Pork</td>
<td>4.9 lbs of feed</td>
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<tr>
<td>1 lb of Turkey</td>
<td>5.2 lbs of feed</td>
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<tr>
<td>1 lb of Lamb</td>
<td>8.0 lbs of feed</td>
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<td></td>
<td></td>
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<tr>
<td>1 lb of Beef</td>
<td>9.0 lbs of feed</td>
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</table>
Estimated U.S. Energy Use in 2010: ~98.0 Quads

Solar 0.11
Nuclear 8.44
Hydro 2.51
Wind 0.92
Geothermal 0.21
Natural Gas 24.65
Coal 20.82
Biomass 4.29
Petroleum 35.97

Net Electricity Imports 0.09
Electricity Generation 39.49
Residential 11.79
Commercial 8.71
Industrial 23.27
Transportation 27.45

Energy Services 41.88
Rejected Energy 56.13

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

https://flowcharts.llnl.gov/content/energy/energy_archive/energy_flow_2010/LLNLUSEnergy2010.png
Better or worse than 2010? Why?