Energy Return on Energy Invested (EROEI)

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**Figure 1.** Schematic of an energy system.
Net Useful Energy & EROEI

With these considerations in mind, the net useful energy available for needs other than the energy system itself, $E_{\text{net}}$, can be expressed in terms of the energy system output energy, $E_0$, and the diverted energy, $E_{\text{div}}$ as

$$E_{\text{net}} = E_0 - E_{\text{div}}$$

(1)

We now define the energy returned on energy invested (EROEI), $E_R$, as the ratio

$$E_R = \frac{E_0}{E_{\text{div}}}$$

(2)

1st Law of Thermo & EROEI Gives

$$E_{\text{in}} > E_{\text{net}} \left( \frac{E_R}{E_R - 1} \right)$$

Deng & Tynan, *Sustainability* 2011, 2433
Estimated EROEI of Some Primary Energy Sources

Table 1. EROEI for energy sources and fuels. Values taken from reference [19].

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Coal</th>
<th>Oil</th>
<th>Gas</th>
<th>Ethanol</th>
<th>Biodiesel</th>
<th>Nuclear</th>
<th>Solar PV</th>
<th>Hydropower</th>
<th>Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>EROEI</td>
<td>50–80</td>
<td>20–40</td>
<td>15–25</td>
<td>1–1.5</td>
<td>1.5–3</td>
<td>5–15</td>
<td>8–10</td>
<td>20–40</td>
<td>15–25</td>
</tr>
</tbody>
</table>

Deng & Tynan, *Sustainability* 2011, 2433
Transitioning to a new energy system

Figure 3. Systems 1 and 2 represent the old and new energy system, respectively.
Transitioning to a new energy system

Assume new technology follows substitution model:

\[ f(t) = \frac{1}{1 + e^{-r_0(t-t_0)}} \]

The old and new energy sources capture all of the market:

\[ f_1 = 1 - f_2. \]

We can then find ratio of TOTAL DEMAND to NET AVAILABLE ENERGY

\[ \frac{E_{tot}}{E_{net}} \geq (1 - f_2)\left(\frac{E_{R1}}{E_{R1} - 1}\right) + f_2\left(\frac{E_{R2}}{E_{R2} - 1}\right) \]

Deng & Tynan, *Sustainability* 2011, 2433
EROEI of new system impacts total energy demand

Figure 4. Plot of $E_{\text{tot}}/E_{\text{net}}$ vs. ratio of EROEI, $E_{R2}/E_{R1}$ for several values of $E_{R1}$.
Transition to lower EROEI sources increases total energy demand

**Figure 5.** Time Evolution for different $E_{R2}/E_{R1}$ ratios.
Conclusions

• EROEI is an important concept!
• We’ve enjoyed high EROEI (>>10) for last 100 years
• Replacement sources tend to have lower EROEI (~10 or so, sometimes lower)
• Impacts the cost, total demand for energy
• Crucial to identify sources with EROEI >2-3!