A Survey of Needs

Towards a Net Energy Analysis Toolkit (and Beyond)

Stanford University—April 1, 2015
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Why are We Here?

How did we get here?

Where are we now?

Where are we going?

How can we get there?
Why are We Here?

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How can we get there?
Quantity and price of applied energy are key drivers of economic output in any society.

<table>
<thead>
<tr>
<th>Energy application</th>
<th>Cost per kWh</th>
<th>Multiple of American human</th>
<th>Multiple of average human</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human in the United States (median)</td>
<td>$260</td>
<td>1</td>
<td>0.22</td>
</tr>
<tr>
<td>Average human (globally)</td>
<td>$57.8</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Human in Bangladesh</td>
<td>$8.26</td>
<td>32</td>
<td>7</td>
</tr>
<tr>
<td>Low cost PV (current), without grid</td>
<td>$0.20</td>
<td>1300</td>
<td>260</td>
</tr>
<tr>
<td>Gasoline at $6 per U.S. gallon</td>
<td>$0.16</td>
<td>1,586</td>
<td>353</td>
</tr>
<tr>
<td>Future CSP (projection), no grid</td>
<td>$0.15</td>
<td>1,734</td>
<td>385</td>
</tr>
<tr>
<td>Gasoline at $4 per U.S. gallon</td>
<td>$0.109</td>
<td>2,387</td>
<td>530</td>
</tr>
<tr>
<td>Natural gas electricity (no grid) at 8$ per 1000 cbf</td>
<td>$0.090</td>
<td>2,891</td>
<td>642</td>
</tr>
<tr>
<td>Oil at $150 per barrel</td>
<td>$0.088</td>
<td>2,956</td>
<td>657</td>
</tr>
<tr>
<td>New large nuclear (no grid)</td>
<td>$0.080</td>
<td>3,252</td>
<td>723</td>
</tr>
<tr>
<td>Electricity from natural gas at 4$ per mcf</td>
<td>$0.060</td>
<td>4,336</td>
<td>964</td>
</tr>
<tr>
<td>Electricity from new coal plant (no grid)</td>
<td>$0.060</td>
<td>4,336</td>
<td>964</td>
</tr>
<tr>
<td>Gasoline at $2 per U.S. gallon</td>
<td>$0.055</td>
<td>4,730</td>
<td>1,051</td>
</tr>
<tr>
<td>Oil at $75 per barrel</td>
<td>$0.044</td>
<td>5,912</td>
<td>1,314</td>
</tr>
<tr>
<td>Electricity from old coal plant (no grid)</td>
<td>$0.020</td>
<td>13,007</td>
<td>2,891</td>
</tr>
<tr>
<td>Natural gas at 4$ per mcf</td>
<td>$0.020</td>
<td>18,582</td>
<td>4,129</td>
</tr>
<tr>
<td>Oil at $20 per barrel (long term average)</td>
<td>$0.012</td>
<td>21,679</td>
<td>4,818</td>
</tr>
<tr>
<td>Coal at $2.50 per MBTU</td>
<td>$0.007</td>
<td>37,164</td>
<td>8,259</td>
</tr>
</tbody>
</table>

Source: IEA, EIA, IIER, others
Fossil Fuels + Solar and labor = Available Output
Global GDP Per Capita since 1000 BC


From Andrew Haldane, Chief Economist BOE, March 2015 speech
The key story of industrialization was adding large amounts of cheap energy to replace activities humans previously did.
30 min 15 min 3 min
0 300kWh 700kWh
$3/hr $5/hr $15/hr
How does technology relate to energy?
How does technology relate to energy?

Human Labor Replacement
New resource Conversions
Resource/Energy Efficiency
New Energy Tech

These technology types create a larger demand for primary energy.
• Money creation in practice differs from popular misconceptions — banks do not act simply as intermediaries, lending out deposits that savers place with them, and nor do they ‘multiply up’ central bank money to create new loans and deposits.

• The majority of money in the modern economy is created by commercial banks making loans.

There is an inflection point I between the monetary claims on non-renewable resources and the availability/cost of these low entropy resources.
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Where are we going?

How can we get there?
GDP (2005$)

Source: World Bank

Global Debt

Net Energy has to increase in order to offset declining ore grades.
Russia – world's 2nd largest oil producer, has a 50% drop in value of their currency.
Median household income peaked at least 15 years ago in 81 percent of U.S. counties.

45 years ago
210 counties peaked in 1909

35 years
572 counties peaked in 1979

25 years
141 counties peaked in 1989

15 years
1,023 counties peaked in 1999

5 years
213 counties peaked in 2009

1 year
380 counties peaked in 2013

The fracking boom lifted counties in North Dakota.

Many populous East Coast cities peaked 25 years ago.

The '90s were a prosperous time for most of the nation.

Note: Gray counties do not have enough data to determine the highest median wage.
Source: U.S. Census Bureau.

CARLA CAMERON AND TED MELLNIK/THE WASHINGTON POST
For most people growth is already over...

Income development 2002-2012, U.S. census data (www.census.gov), graphic IIER
Are We Looking at the Wrong “Cost of Capital”?

US 10 YEARS TREASURIES YIELD vs ESTIMATED FULL LIFE CYCLE BREAK EVEN COSTS FOR OIL FOR THE MAJORS

Data Source: EvaluateEnergy “Breakeven Cost of Global Oil and Gas Production 12/2014”
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WE ARE BEING CONTROLLED BY THE RANDOM OUTCOMES OF A COMPLEX SYSTEM
Gross vs net energy becomes very important

Source: CBO 2014
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How can we get there?
More physical scientists (publicly) acknowledging the economy as a physical system.
2. Expand
We need more and better data
Net Energy analysis needs an open source clearinghouse of assumptions, boundaries and conventions

5. The Agenda of the Mind >= the Agenda of the Gene
Biophysical/Net Energy Metrics

$, Euro, Yen
Stanford Net Energy Analysis Conference 2055?
A SURVEY OF NEEDS

1. There need to be more natural scientists acknowledging the human economy as a physical system.

2. We need to expand the demographic who uses biophysical metrics, horizontally and vertically.

3. We need better data in energy terms.

4. We need a standardized methodology/clearinghouse so everyone uses the same boundaries or indicates otherwise.

5. ‘Acting for the future’ is against the grain of how our brains work – so is thinking in energy instead of $ terms but we need to do it.
Thank you.