Ecology and Economics: It's Also About Resources, Not Just Jobs and Deficits

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OUT OF AFRICA

INTO THE 21ST CENTURY
50,000 years of

- Exponential increase in population and resource use
- Global geographic expansion
- Unprecedented ecological dominance
HUMAN POPULATION GROWTH CHART
(including projections)

I THINK I CAN...
I THINK I CAN...
I HOPE I CAN...
I REALLY HOPE I CAN...
MAN, I HOPE I CAN...

YEAR

1 AD 200 400 600 800 1000 1200 1400 1600 1700 1800 1900 2000

BILLIONS

0 2.5 5 7.5 10 12.5 15

GREENBERG—SEATTLE POST-INTELLIGENCER, 1994
How much longer can current trajectories of growth and development be maintained?

Optimistic projections for 2050:
• Population: 1-2% per year, 9-10 billion
• Economy: 4% per year, “lift developing countries out of poverty”

These are exponentials which cannot be continued indefinitely in a finite environment

Are “sustainability” and “sustainable development” assumptions, hypotheses, oxymorons?
Icons of sustainability re-examined?

Bristol Bay salmon fishery
“a model of successful natural resource stewardship”

Portland, Oregon
“The most sustainable city in America”
Bristol Bay salmon fishery
“A model of successful natural resource stewardship”
Bristol Bay salmon fishery

70% of wild salmon harvested, sockeye 95% of catch

Evidence of sustainability
• Harvests have been steady 2007-2009

Causes for concern
• Export of 83,000 metric tonnes of salmon biomass:
  12,000 t Carbon, 2,500 t Nitrogen, 330 t Phosphorus
• In Lake Nerka “this loss of MDN (marine derived nutrients) has reduced lake algal productivity to about 1/3 of its level before commercial fishing” Schindler et al. (2005)
• Effects on terrestrial and riparian ecosystems, predators, scavengers, subsistence fishers?
Bristol Bay salmon fishery
Portland, Oregon

City of Portland and Multnomah County
• population 715,000, median income $51,000

Imports/consumes
• 1.25 billion liters of gasoline
• 28.8 billion megajoules of natural gas
• 31.1 billion megajoules of electricity
• 136 billion liters of water
• 0.5 million tonnes of food

Exports/releases
• 8.5 million tonnes of carbon as CO₂
• 99 billion liters of liquid sewage
• 1 million tonnes of solid waste
Portland, Oregon
Humans have always used local ecosystems unsustainably

- Importing resources
  - Energy, food, water, minerals

- Exporting wastes
  - CO2, sewage, chemical
GLOBAL SUSTAINABILITY:
ENERGY AND ECONOMICS
Energy and economics

- Energy powers the economy
- GDP tracks per capita energy use across nations and over time
- Most energy comes from fossil fuels
- Implications for economic growth and "sustainable development"
Global population and energy use

Smil (2010)
Global economy and energy use

Hirsch (2008)
Kleiber’s law: metabolic rate scales as $3/4$ power of body mass (from Kleiber 1932)
Per-capita energy use vs. per capita GDP
25-year trends

Data compiled and analyzed by M. Hamilton
Problem:
1) Massive quantities of energy will be required for projected economic growth and development

Solutions:
1) Increase supply to meet expected demand
2) Reduce demand by reducing population
3) Reduce demand by reducing consumption
Possible solutions

1) Increase supply of energy to meet expected demand

• How much energy will be required?
• Where will it come from?
### Total annual global energy consumption in different economic scenarios

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<thead>
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<th>EJ</th>
<th>factor</th>
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<tr>
<td>world current</td>
<td>524</td>
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<td>U.S. lifestyle</td>
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<td>Chinese lifestyle</td>
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<td>current trends to 2025*</td>
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<td>U.S. lifestyle in 2025*</td>
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<td>Chinese lifestyle in 2025*</td>
<td>848</td>
<td>1.6</td>
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*Assumes 2025 world population of 8 billion (U.S. Census Bureau) and 3.8% per year increase in global GDP (World Resources Institute)

Data compiled and analyzed by W. Zuo
Current global energy use

Current global energy use

Fossil fuels 85%
(oil, gas, coal)

“Renewables” 9%
(solar, wind, geothermal, tidal)

Nuclear 6%

Past, present and future oil supply

![Graph showing oil supply over time](image)

 Courtesy of G. Tverberg
Possible solutions

2) Reduce demand for energy by reducing population

• take advantage of the “demographic transition” (UN model) but see DeLong et al. 2010 (PLoS 1)

• something more drastic – like China’s one child policy?
Stabilizing population growth – achieving the demographic transition by increased energy use

DeLong et al. 2010
Projected population growth

- past history
- UN model
- current trend
- redistribute energy

DeLong et al. 2010
Possible solutions

3) Reduce demand for energy by reducing per-capita consumption

• increase efficiency – limited gains and must counter “Jevon’s paradox”

• curtail lifestyle – “there is no such thing as a free lunch”
It is not just GDP

No such thing as a free lunch

Other metrics of quality of life are all correlated with GDP and energy use.
It’s not just oil

Per capita rates of consumption of other critical resources are decreasing

--- per capita

--- total
TRAGEDY OF THE COMMONS

MARINE FISHERIES
Resource use and economic growth
China and US, 2000-2010

% annual change

GDP  Energy  Water  Copper  Fisheries  Phosphate

China
US
Sustainable development: assumption, hypothesis, oxymoron?

“Sustainable development … meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Sustainable development: assumption, hypothesis, oxymoron?

To “get the economy growing again” and “lift developing countries out of poverty” will require enormous quantities of energy.

Exponential growth cannot continue indefinitely in a world of finite resources.

Per capita supplies of many critical resources have been declining since the 1980s.

Much of economics is human ecology.
The biggest obstacle to sustainability is human nature
The biggest obstacle to sustainability is human nature.

 Aren’t you worried?

 No, ingenuity and technology will save us again.
"I can't think about that right now. If I do, I'll go crazy. I'll think about that tomorrow."

Scarlet O’Hara
Collaborators: New Mexico
“Human macroecology” group: Craig Allen, Robbie Burger, Bill Burnside, Ana Davidson, Trevor Fristoe, Marcus Hamilton, Norman Mercado-Silva, Jeff Nekola, Jordan Okie, Wenyun Zuo

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Dedicated to my grandchildren

SONNY (11) AND QUINTON (7) DUQUETTE

MEREDITH (10) AND RHYS (7) BROWN
BIRTH RATES IN MODERN NATIONS

↑ developing world

← developed world
POWER AND APPLICATIONS OF HUMAN MACROECOLOGY

• NON-EXPERIMENTAL BUT RIGOROUS AND QUANTITATIVE

• LARGE SCALES OF SPACE AND TIME

• STATISTICAL PATTERNS CALL FOR MECHANISTIC PROCESSES

• DON’T NEED HUMAN SUBJECTS PROTOCOLS
THE DUALITY OF *Homo sapiens*
ON ONE SIDE:

- JUST ONE OF MILLIONS OF SPECIES

- SUBJECT TO THE SCIENTIFIC LAWS
  PHYSICS AND CHEMISTRY:
  CONSERVATION OF ENERGY, MASS, STOICHIOMETRY
  BIOLOGY:
  MALTHUSIAN-DARWINIAN DYNAMIC

- SUBJECT OF NATURAL SCIENCES
  BIOMEDICINE, ECOLOGY
THE DUALITY OF Homo sapiens
ON THE OTHER SIDE:

HUMANS ARE UNIQUE

• BRAIN AND BEHAVIOR,

• AGRICULTURAL, INDUSTRIAL, TECHNOLOGICAL ECONOMY

• THE ECOLOGICALLY DOMINANT SPECIES

• SUBJECT OF SOCIAL SCIENCES PSYCHOLOGY, SOCIOLOGY, ECONOMICS
Per-capita energy use vs. per capita GDP

$y = 4.13x^{0.76}, \quad r^2 = 0.76$

Data compiled and analyzed by M. Hamilton
Per-capita energy use vs. per capita GDP

Slopes over 25 years, 1980-2005

Mean = 0.59 (95% CI 0.45-0.72)

Data compiled and analyzed by M. Hamilton
Other metrics are all correlated with GDP and energy use

- consumption of aluminum, wood, residential energy, gasoline, electricity, coal, meat, coffee, calories
- production of waste
- number of doctors, life expectancy, infant mortality, poverty level, population growth rate
- carbon and ecological footprint
- imports, exports
- patents, Nobel Prizes
It’s not just oil

Per capita rates of consumption of other critical resources are decreasing
ENERGY AND ECONOMICS: 
a macroecological and metabolic perspective

- GDP tracks per capita energy use across nations and over time
- Energy fuels economic growth and development
- All measures of standard of living are correlated with energy use and GDP
- Most energy comes from fossil fuels
- Limited potential to substitute renewable sources
- Implications for “getting the economy growing again”
  “sustainable development”

Third World must develop or die (BBC 2/12/09)
Per-capita energy use vs. per capita GDP
25-year averages for alternative scenarios

\[ y = 4.06x^{0.76}, \quad r^2 = 0.76 \]

Mean per capita total power consumption, watts

Mean per capita GDP (constant US$, 2000)

Data compiled and analyzed by M. Hamilton
NO, INGENUITY AND TECHNOLOGY WILL SAVE US AGAIN

ARE YOU WORRIED?
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UNM/SFI/LANL scaling group: