UNDERSTANDING THE ENERGY-FOOD NEXUS

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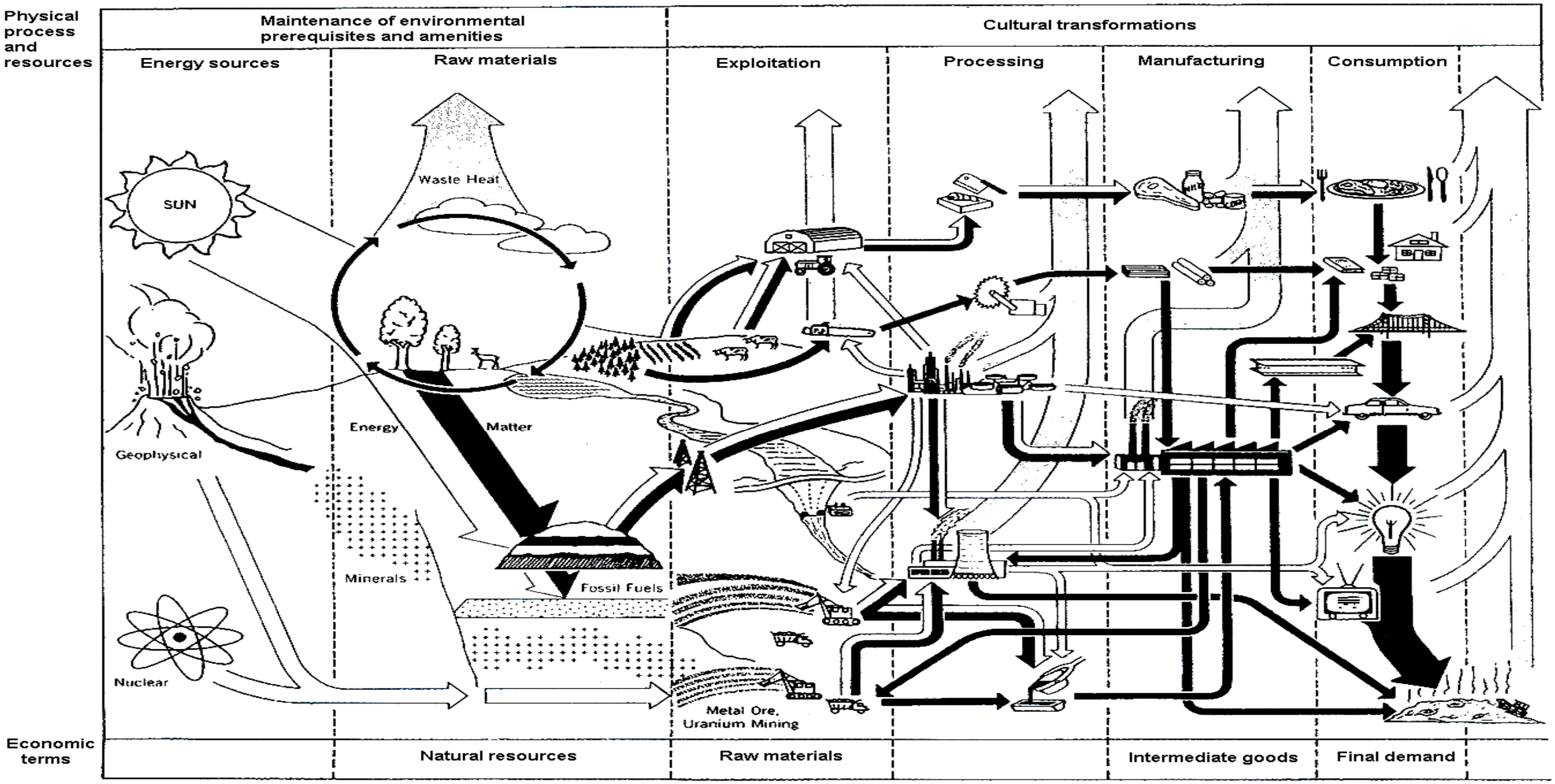
Food and energy

- Relationship between food and energy, concept often not understood
  - Super markets! Detach consumers from ground realities.
  - Farming systems?
  - Inputs?
  - Distances?



Hall *et al*. 2007

Eat Here

A meal made from **imported** vs **local** ingredients in Britain generates 650 times more transport-related carbon emissions

All these food items can be grown in a British climate

Strawberries
8,772 km
CALIFORNIA

Broccoli
8,780 km
GUATEMALA

Blueberries
18,835 km
NEW ZEALAND

Beef joint
21,462 km
AUSTRALIA

Potatoes
2,447 km
ITALY

Runner beans
9,532 km
THAILAND

Carrots
9,620 km
SOUTH AFRICA

Source: Jones

Why not monetary metrics?

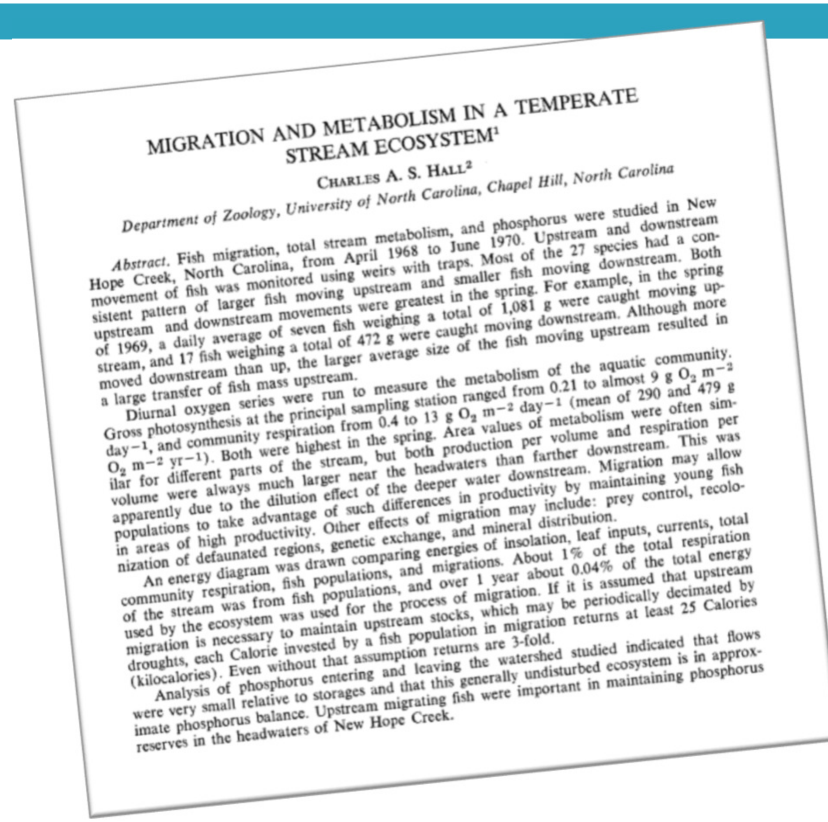
- Is price a good indicator of the energy going into a process?
- Dollars are distorted by many variables
  - e.g. markets, public policies

Energy return on investment

EROI

Energy return on investment (EROI)

- Originally a methodology to assess the evolutionary advantage of fish migration
- Hall 1972



MIGRATION AND METABOLISM IN A TEMPERATE STREAM ECOSYSTEM[1]

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Abstract. Fish migration, total stream metabolism, and phosphorus were studied in New Hope Creek, North Carolina, from April 1968 to June 1970. Upstream and downstream movement of fish was monitored using weirs with traps. Most of the 27 species had a consistent pattern of larger fish moving upstream and smaller fish moving downstream. Both upstream and downstream movements were greatest in the spring. For example, in the spring of 1969, a daily average of seven fish weighing a total of 1,081 g were caught moving upstream, and 17 fish weighing a total of 472 g were caught moving downstream. Although more moved downstream than up, the larger average size of the fish moving upstream resulted in a large transfer of fish mass upstream.

Diurnal oxygen series were run to measure the metabolism of the aquatic community. Gross photosynthesis at the principal sampling station ranged from 0.21 to almost 9 g O_2 m^{-2} day^{-1}, and community respiration from 0.4 to 13 g O_2 m^{-2} day^{-1} (mean of 290 and 479 g O_2 m^{-2} yr^{-1}). Both were highest in the spring. Area values of metabolism were often similar for different parts of the stream, but both production per volume and respiration per volume were always much larger near the headwaters than farther downstream. This was apparently due to the dilution effect of the deeper water downstream. Migration may allow populations to take advantage of such differences in productivity by maintaining young fish in areas of high productivity. Other effects of migration may include: prey control, recolonization of defaunated regions, genetic exchange, and mineral distribution.

An energy diagram was drawn comparing energies of insolation, leaf inputs, currents, total community respiration, fish populations, and migrations. About 1% of the total respiration of the stream was from fish populations, and over 1 year about 0.04% of the total energy used by the ecosystem was used for the process of migration. If it is assumed that upstream migration is necessary to maintain upstream stocks, which may be periodically decimated by droughts, each Calorie invested by a fish population in migration returns at least 25 Calories (kilocalories). Even without that assumption returns are 3-fold.

Analysis of phosphorus entering and leaving the watershed studied indicated that flows were very small relative to storages and that this generally undisturbed ecosystem is in approximate phosphorus balance. Upstream migrating fish were important in maintaining phosphorus reserves in the headwaters of New Hope Creek.

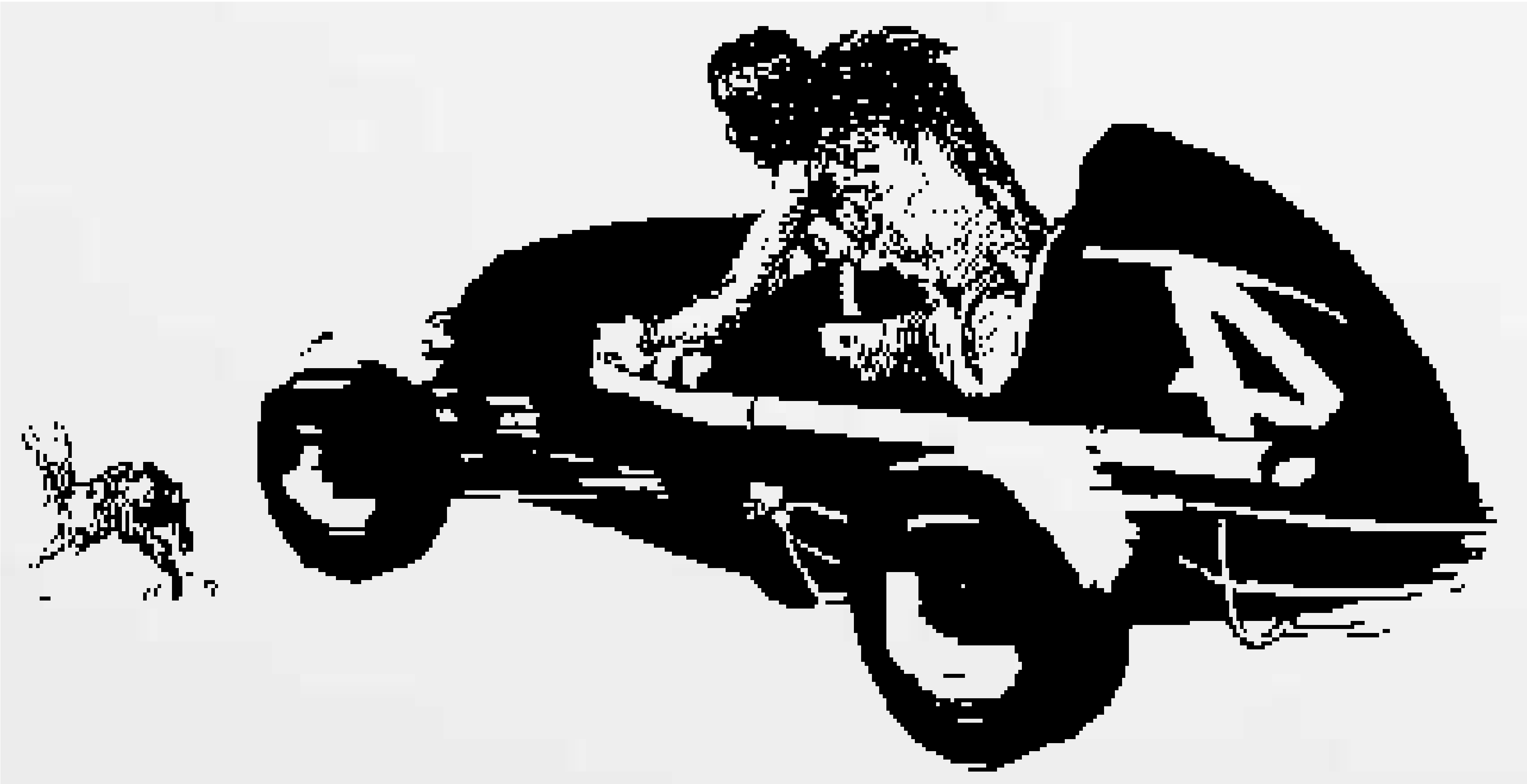
What is EROI?

- Energy return on investment OR
- (energy returned on energy invested)

- $\text{EROI} = \dfrac{\text{energy gained from an activity}}{\text{energy used in that activity}}$

Hall, 1981

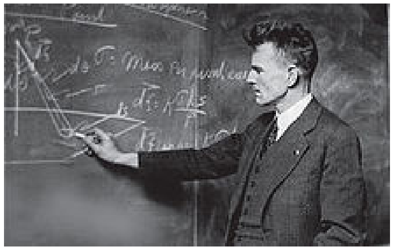
Günther, 2006



Günther, 2006

A Very Famous Example

- Petroleum drilling and production in the United States: Yield per effort and net energy analysis
- Hall and Cleveland, 1981
  - An extension of the work of M. King Hubbert
  - Energy found per foot of drilling for oil/gas ↓ about 50–15 barrels (1946–1978)
  - Implied EROI ↓ 50:1 to 8:1



Examples from food

- **Ozkan et al., 2004**
  - Turkish agriculture
  - Energy output/input ratio, 1975–2000
  - EROI ↓ 2.23–1.12
  - 1975–2000

Examples from food…

- **Pracha and Volk, 2011**
  - Wheat production in Pakistan
  - EROI avg. 2.9 (1999–2009)

  - Rice production in Pakistan
  - EROI avg. 3.9 (1999–2009)

Examples from food…

- **Refsgaard et al.,1998**
  - Farms in Denmark
  - Increased yields not sufficiently high to compensate for extra energy used compared with organic practices

Examples from food…

- **Pimentel et al., 1973**
  - **Showed increasing dependency on fossil energy**
  - 1945–1970
  - Due mainly to N fertilizer.
  - Also showed that energy required/ha for conventional farms significantly higher than that of organic farms, due primarily to the inputs

Examples from food…

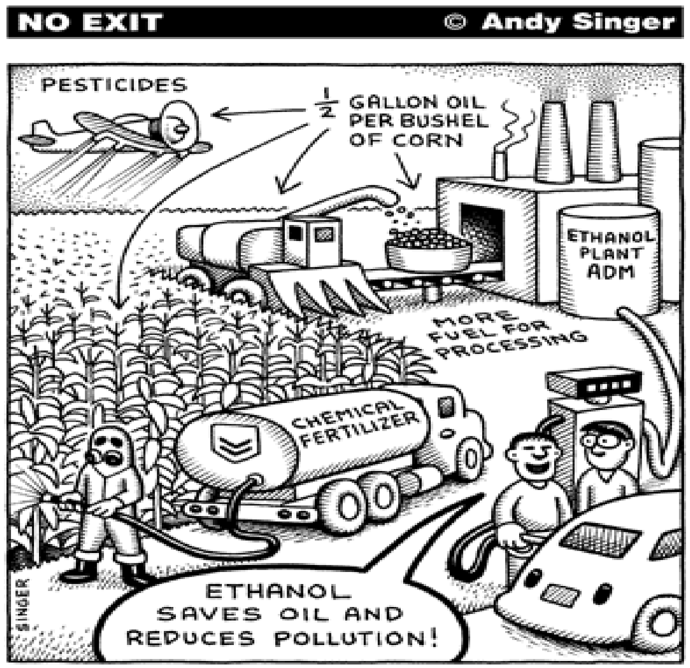
- *"Not only is the technology itself keyed to energy from fossil fuels, but the research establishment that developed the technology also is oriented to exploitation of this resource"*

  Crosson and Brubaker, 1982

Boundary issues

- What to include in analysis?
- Seed, fertilizer, pesticide, irrigation?
- What else?
- Different thoughts on this.

Increasing the energy input…

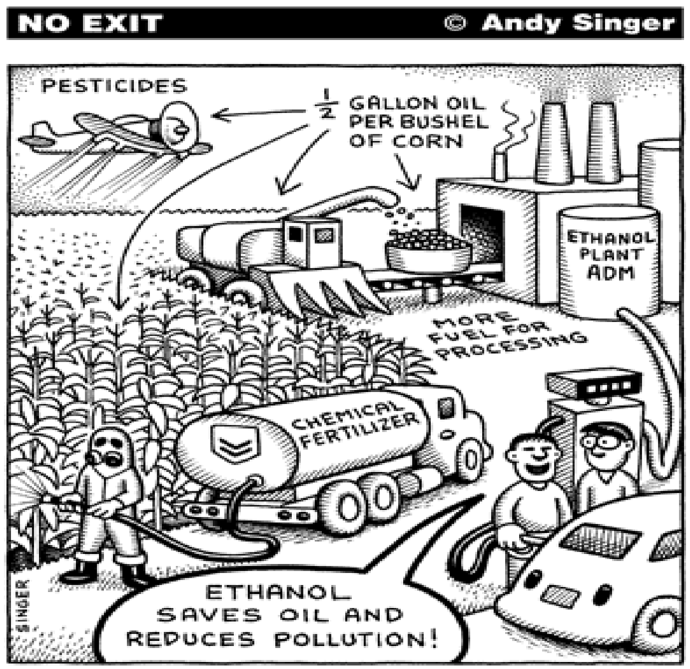


- ↑ in crop yields
- More land use for energy crops
- Extensive use of no-till agricultural practices

Singer

Hall *et al.* 2008

But this means…(cont.)



Singer

- More fertilizer (and natural gas feedstock)
- More irrigation
- More tractor horsepower
- More soil erosion

Hall *et al.* 2008

Food security

"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"

(FAO 1996)

Exercise for students

- What would it take to achieve food security?
  - Type of staple food, eating habits
  - Available agricultural land area
  - International trade relations (imported food?)
  - Transport
  - Expensive technology transfer/import
  - Increased energy use
  - Increased energy imports

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