

Net Energy and the Economy George Mobus, Ph.D., Associate Professor, Institute of Technology, University of Washington Tacoma

Overview

- What is Net Energy? What is the problem?
- How is it Related to the Economy?
 - Economic Work
 - Macroeconomic View
 - Microeconomic View
- What is Happening with Net Energy?
- What Are the Consequences?

Why Focus on Net Energy?

- Current focus on gross or raw energy resources and peak oil
- Net energy is ALWAYS less than gross inputs
- Net energy is what the economy runs on
- Net energy has already peaked!
- What does this mean for the economy?

Energy and Work

- All economic work is accomplished with high power energy inputs
- Types of energy are coupled with the prime movers, heaters, appliances
 - Oil \rightarrow diesel \rightarrow ICE \rightarrow moving people & stuff
 - Coal → boiling water → driving turbines → generating electricity → lighting the house
 - $\circ~$ Natural gas \rightarrow mixed uses, transportation, heating, electricity
- The final use determines the economic benefit – covered later



Energy Costs

Example: Refining oil into diesel requires using some of that fuel (or its energy equivalent) to keep the process going.



What Is Net Energy?

- Raw or Gross Energy
 - barrels of oil
- Energy Capture and Conversion
 - oil exploration, drilling, pumping, transporting, and refining
- Energy used to capture and convert to usable form
 - building capital equipment (investment)
 - operations: labor, pumping, transporting
- Energy Return on Energy Invested

Usable Energy Stream



gross energy energy invested energy delivered







Net Energy

- Usable energy form after capture and conversion, e.g. gasoline with high energy content per unit volume (weight)
- Net energy is used to either:
 - get more energy
 - used by the productive/consumption economy
- Net energy to the economy, NEE

NEE t+1 = GE \overline{t} NEI t-1



Principles

- Absolutely nothing happens (no work gets done) without a flowthrough of high potential energy.
- All energy eventually degrades to waste heat (2nd Law of Thermodynamics).
- To produce high quality usable energy requires energy be reinvested. Net energy to society is less than the raw energy input.



Additional Important Considerations

- As the raw energy from fixed finite resources, like fossil fuels, are depleted the amount of high-grade energy needed to reinvest to obtain new energy increases.
- Energy return on energy (re) invested (EROI) diminishes over time.
- Without new sources of renewable energy (real-time solar, wind, etc.) that scale up to replace the lost fossil fuels, the net energy to society continues to decline.
- Peak oil is a test case.



Economic Work The physics definition of work mechanical (motors moving things) electrical (convertible to mechanical) chemical biophysical/chemical Economic work (definition) changing material forms for use moving material goods providing services

• any activity that supports human life

Economic Work – A Simple Example: Getting Food

- Catching by hand
- Investing some of your energy (effort) in constructing a spear
- Increasing the efficiency of obtaining the next unit of food
- More food to supply offspring
- Teach offspring to make spears
- Ultimate products: More human biomass

Basic Model: Primitive Economics



Energy Efficiency – Technology and Productivity

- The historical benefit of technology has generally been to increase the efficiency of work processes.
- Increasing technology increases complexity
- Local vs. Global efficiencies
- Jevons' Paradox
- Productivity should not be confused with efficiency
- Effects of rapid expansion of raw energy availability
- Effects of initial technology improvements and Law of Diminishing Returns

Biophysical Macroeconomic View



Relationship Between Energy and Money

Howard Odum, and others



An impossibility theorem: The money spent to purchase must << than the money used to pay wages!

Net Energy Investment



Building buildings and equipment

Capturing & converting raw energy into usable energy requires a whole substructure of production that takes considerable energy to grow, maintain, and operate.

If raw energy source is shrinking, then it is necessary to boost energy/material inputs to compensate. Which means less net energy to support the consumer economy.

An Economy Dependent on Fossil Fuels



Total assets = All artifacts and all biomass

Net Energy Peak and Decline

- We are already in net energy decline from fossil fuels
- Diminishing EROI in fossil fuel extraction, conversion, and distribution
- Renewable (alternative) sources cannot scale up anytime soon
- Renewables may not have a sufficiently high EROI to be sustainable

The Future of Economic Work

- Declining net energy means less work can be accomplished
- Channel remaining energy resources away from esthetic and hedonic products and toward appropriate technology
- Technology that increases global net energy should be favored



Conclusion

- The economy must necessarily contract as the total net energy available to do useful work declines
- Since >80% of our energy comes from fossil fuels, and since oil extraction rates appear to have topped out, our net available energy is already in decline
- We had better find ways to better manage what energy flows we have left



Thank you

• Q & A