Background

The concept of net energy has been around for decades and came into prominence after the first oil crisis in 1973. One common metric of net energy is “energy return on energy invested” (EROI) (Hall et al., 1986). EROI is equal to energy production divided by the energy inputs required for that production. All things being equal, an energy resource with higher EROI is more economical as EROI and price are inversely related (King, 2010; King and Hall, 2011). Thus, tracking trends of EROI over time provides insight as to whether energy is getting more or less costly (in terms of energy inputs) over time.

Declining EROI implies resource depletion is “winning” over gains in extraction technology and efficiency. Further, studies of preindustrial societies implies that societies need to increase complexity to solve new problems, and that this complexity necessitates increased energy consumption and/or higher net energy supplies (Tainter, 1988). Thus, EROI is one metric for assessing if our energy supplies are capable of sustaining and increasing societal complexity.

Methods

Here we calculate an EROI for various countries as energy production divided by energy consumption (Equations (1) & (2)). The EROI for the world is a production-weighted average (Equation (3)). We use energy industry own use (EIOU) data from the International Energy Agency (IEA) as an estimate of the direct energy consumed by the energy industry to produce energy, e.g., the consumption of oil or gas in order to produce the same. We do not yet include estimates of indirect energy inputs that represent embodied energy in capital (e.g., materials, services) and labor (e.g., salaries). Both direct and indirect energy represent substantial portions of inputs to fossil energy extraction (Guiffrida et al., 2011). We do not include indirect energy due to lack of data.

IEA describes 'energy industry own use' (EIOU) as “… shows the quantities of energy commodities consumed within the fuel and energy enterprises…” and “The commodities are used to support the various activities within the fuel extraction, conversion or energy production plant but they do not enter into the transformation [from primary energy to energy carrier] process.” (IEA, 2005).

**Energy Production**

\[
\text{Energy Production}_{\text{country}} = \sum_{\text{source}} \text{quantity or} \text{energy density} \times \text{energy density}_{\text{source}}
\]

**EROI for country**

\[
\text{EROI}_{\text{country}} = \frac{\text{Energy Production}_{\text{country}}}{\sum \text{Energy Production}_{\text{country}}}
\]

**World Average EROI**

\[
\text{EROI}_{\text{world}} = \frac{\sum \text{Energy Production}_{\text{country}} \times \text{EROI}_{\text{country}}}{\sum \text{Energy Production}_{\text{country}}}
\]

Observations for World EROI

- The data can be split into two groups due to the addition of multiple country data sets in 1990 (Fig. 1): Pre-1990, a minimum EROI value of ~12 was reached in 1974, and the overall trend 1960-1990 was that of a slight increase.
- Post-1990, a minimum EROI value of ~19 was reached in 2005, and the overall trend 1990-2010 was that of a slight decrease.
- The following summarizes countries with large, consistent movement over time:
  - Indonesia: Increasing EROI
  - Russia, Czech Republic:
  - Iran, Iraq, Norway, New Zealand: Decreasing EROI
- Out of 48 total countries, 12 (25%) in 2010 had an EROI value greater than the world average (Fig. 1 inset).
- Ratio profiles vary between steady or volatile. EROI volatility seems to be linked to both high EROI values as well as high exports of crude oil (Fig. 1).

**Observations for importers, exporters, and top producers**

- **Top importers** across coal, natural gas liquids + crude oil, and natural gas were consistently limited to a small group of countries (Fig. 3B). Top exporters spanned a wider range of countries (Fig. 4).
- The major importers in Fig. 3 have EROI ~ world average EROI (Russia is an exception).
- Higher (> world average) EROI values largely include exporter countries (Fig. 4). Of note is the volatility present among these countries. This latter trend seems to be primarily restricted to crude oil exporters, with the exception of volatility for Norway (natural gas) and South Africa (coal).
- Though high exports (Ti) for a single energy type imply high production, high total production does not necessarily imply high volatility (Fig. 2). Russia and the United States both have relatively consistent EROI, and Saudi Arabia’s values have leveled out in recent years.

**References**


IEA Energy Balances, and Energy Statistics available in the Beyond 20/20 Global Database.


