Bioenergy EROI: Towards a More Sustainable Civilisation?

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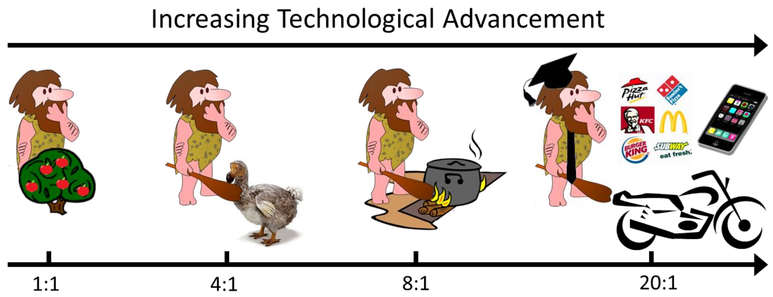
Project Outcomes

1. **Determine whether Bioenergy systems can produce high EROI values.**
2. **Project how societal EROI ($EROI_{soc}$) will change by 2050.**
3. **Understand potential socio-economic implications of a society based on growth using current economic models.**

What is EROI?

The ratio between the energy the produced and the energy required to obtain the produced energy. E.g. Humans: the energy produced is energy metabolised from food. The energy required is the energy used to keep the human alive and obtain the food.

Higher EROI values imply more energy produced per unit of energy spent.
This **excess** energy can be put to use and in the case of humans is usually spent on leisure time. A driving factor for increasing EROI is the advancement of technology.



In prehistoric times cavemen could only forage for fruits and vegetables. With the advent of weapons and fire more calorific meals could be created. Further advancements such as fast food and vehicles have significantly increased humans EROI.

Power plants and Fuel Extraction

EROI can be applied to power plants and the energy sector by investigating the required energy to extract, process and deliver a fuel to society. This can be simplified into equation 1 and 2 below where E_{out} is the produced or output energy and E_{in} is the input or required energy to produce the output energy[1] .

Eq 1 - $EROI = \frac{E_{out}}{E_{in}}$

Eq 2 - $E_{in} = E_{op} + E_c + E_d$

For the purposes of power plants E_{in} is further expanded to the E_{op} (operation and maintenance energy costs), E_c (plant construction energy costs) and E_d (decommissioning energy costs).

Adnams Anaerobic Digester (AD)

The Adnams AD utilised beer and food waste to produce high quality (>95%) methane gas which is injected into the national grid. A bi-product is digestate which is used as fertiliser by the farmers who produce beer crops for Adnams.

Two EROI types were calculated[2]:

1. $EROI_{stnd}$ – Includes the values mentioned in Eq 2 without upgrading biogas to biomethane or transport and labour costs
2. $EROI_{2,i}$ – Includes the values mentioned in Eq 2 with energy costs of upgrading biogas to high quality biomethane without labour and transport costs [2]

Conclusion:
Some bioenergy systems can produce similar EROI values to present day fossil fuels!

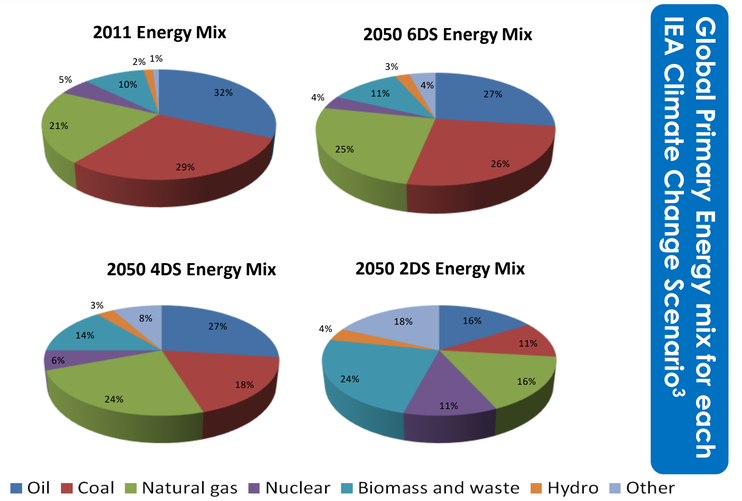
EROI Type	EROI Value (:1)	With co-product (:1)
$EROI_{stnd\ (1,i)}$	15.6	20.3
$EROI_{2,i}$	11.4	15.8

Typical EROI values for fuels are:
- **Chinese coal 24-28:1**
- **Chinese oil 8-14:1**
- **Russian oil 22-35:1**
- **USA corn ethanol: 0.8-2:1**

IEA climate Change Scenarios and Implications for societal EROI

Societal EROI ($EROI_{soc}$) is an important tool for illustrating the potential robustness of a particular energy mix. Meanwhile, the IEA's climate change scenarios project what the energy mix of 2050 could look like, depending on the mobilisation of climate change mitigation. Thus, by calculating the $EROI_{soc}$ of each scenario it is possible to interpret the consequences for global sustainability , depending on the role of bioenergy.

Global Primary Energy mix for each IEA Climate Change Scenario[3]



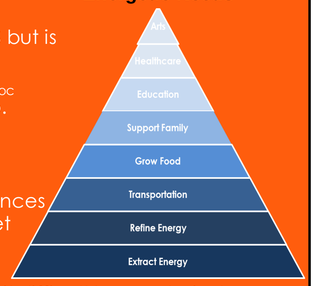
The EROI for bioenergy systems (BEROI) can be extremely variable – ranging between 0.72-28. This span of values suggest the future of BEROI could be either very bleak or highly promising.
Resultantly, a robust average BEROI could not be formulated and pessimistic (4.0) and optimistic (12.0) BEROI scenarios were allocated to estimate the 2050 global $EROI_{soc}$
By combining expected declines in oil and gas EROI (associated with their waning stocks) alongside the EROI of the remaining energy mix fractions a number of potential global $EROI_{soc}$ scenarios have been projected.

$$EROI_{soc} = \frac{Summation\ of\ the\ energy\ content\ of\ all\ fuels\ delivered}{Summation\ of\ all\ the\ energy\ costs\ to\ get\ those\ fuels}$$

Results

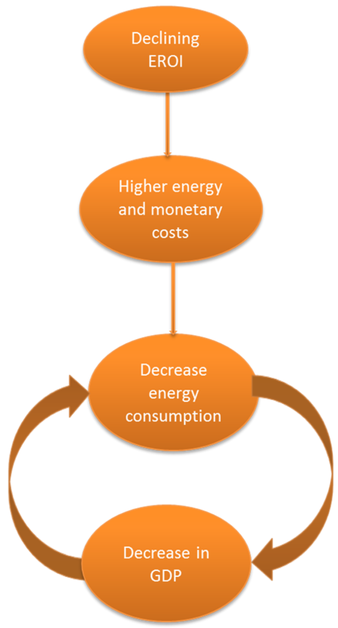
- By 2050 $EROI_{soc}$ is expected to drop anywhere between 29-38%.
- Societal EROI in 2050 is lower under the 2DS but is boosted with high BEROI inputs.
- Maximising BEROI could boost global $EROI_{soc}$ by as much as 13% under the 2DS scenario.
- However, even under an optimistic BEROI scenario, bioenergy systems won't yield as much net energy as oil until 2035.
- These findings imply some major consequences for the society of 2050 – with diminishing net energy to fuel the activities at the top of society's hierarchy of energetic needs.
- However, current economic models make it difficult to conclusively interpret consequences for overall sustainability.

Society's Hierarchy of Energetic Needs[4]



Total primary energy demand (PJ)	2011	6DS	4DS	2DS
Total	549 056	928 692	833 991	680 592
EROIsoc (pessimistic BEROI)	24	16.23	15.85	14.77
$EROI_{soc}$ (optimistic BEROI)	24	17.13	16.96	16.68

The Correlation Between Energy Use and Economic Growth



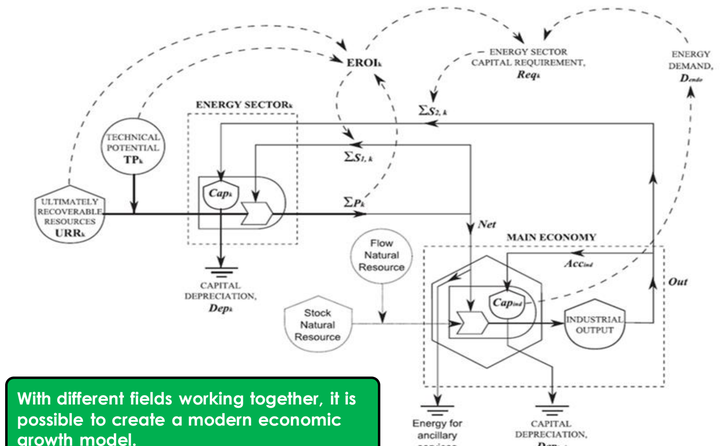
There is a strong positive correlation between energy use and GDP growth [5], but standard economic models do not include energy within their calculations.
A declining EROI suggests it is becoming more expensive to drill for fossil fuels because of their geographical location.
It also means there are higher energy cost as more energy is used to extract the harder to reach fuels.
An increase in prices → decrease in demand for energy → decrease in GDP → decrease in demand for energy: this becomes a circular process which needs to be broken.

How can this be achieved?

1. Boosting the sustainability of renewables such as bioenergy, wind, solar
2. A different focus other than economic growth such as HDI, steady-state economy
3. Collaboration between fields to create a modern economic growth model

An Economic Growth Model Encompassing EROI

The **Exosamatic Hypercycle[6]**, proposed by Dale (2012) is a demonstration that energy (specifically EROI) can and should be included within economic growth.
The complex and more realistic model is able to analyse the economic consequences when more 'unconventional' conditions change.
It incorporates a number of economic branches expanding upon past and present models of growth.
It is one of the most robust economic models integrating EROI and its development is necessary to forecast the economic implications of our drastically altering energy mix.



With different fields working together, it is possible to create a modern economic growth model.

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