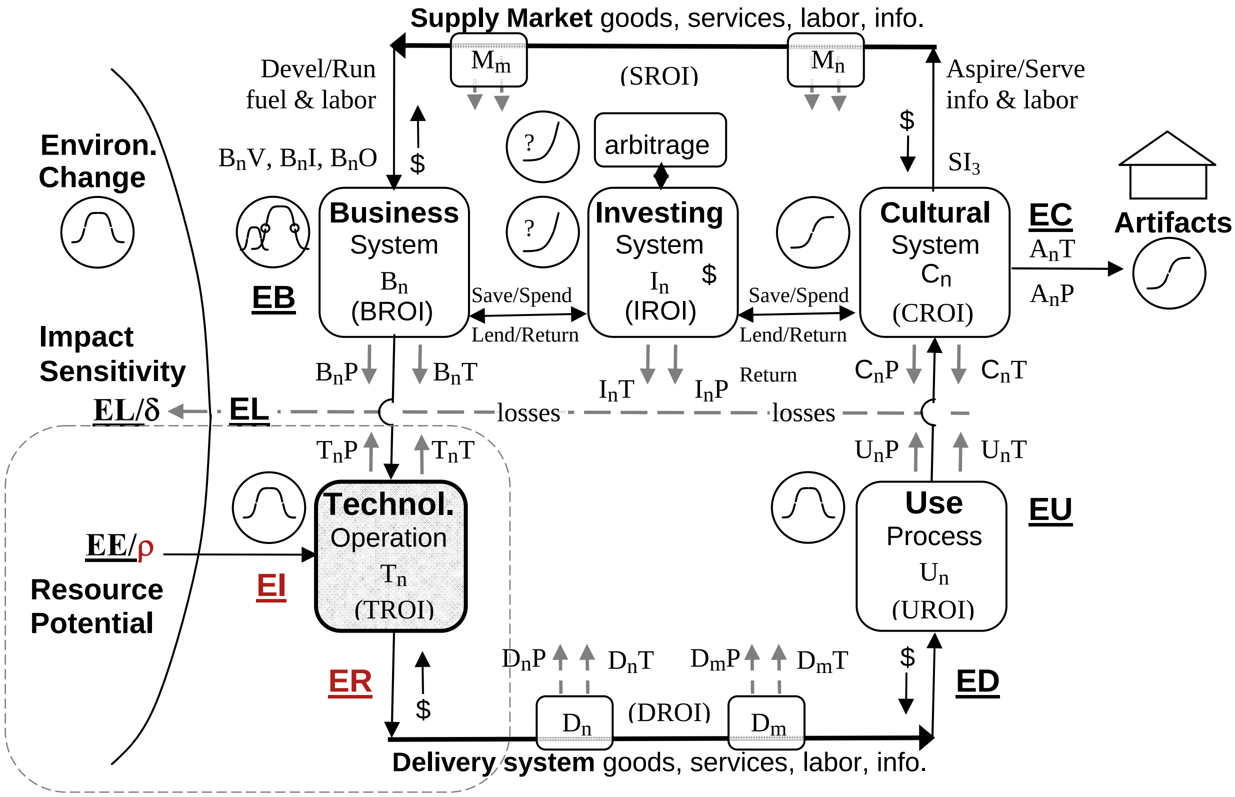
Energy Transformation Process - (and total resource investment over time)



- Invest * Gain = Return + Loss $\quad EI \cdot EROI_T \cdot \rho = ER = ED + EL$
- Delivered & Technology & People cost $\quad ER = ED + (\sum nT\text{'s} + \sum nP\text{'s})$
- Adj. Rate of Gain $\quad EROI_T = TROI \cdot DROI \cdot UROI \cdot CROI \cdot IROI \cdot SROI \cdot BROI$

The questions:

- How much of the earnings from a technology are needed to run it, and repay its development?
- How do you adjust for the costs of the system it is part of, and its resource potential & sensitivity to impact?
- Would alternate energy sources that seem good, also support a system without non-renewable resources?
- Is the potential of a natural resource falling below the sustainable level for supporting the system?

The basic idea: 1)An easy way to adjust the productivity gain of a technology system 2) to mix exact and rough estimates for all unknowns, 3) find the EROI needed to break even, 4) and attract investment, 5) as a whole life cycle investment, 6) in the interests of the culture.

The basic resource use life cycle story: Each step moves energy and uses energy.
1) Using a prior surplus, 2) to start a business, 3) and a technology, 4) converts a resource, 5) to a needed product, and 6) returns a surplus to 7) expand, 8) adapt and maintain, 9) which declines and ends, when the need declines or the costs rise.

The basic equations are: $EROI_{Total} = TROI \cdot DROI \cdot UROI\ CROI \cdot IROI \cdot SROI \cdot BROI - TROI \cdot \delta$

- If Oil has a Gain (Return on Energy Invested)(TROI) of 20btu/btu, and 6 sectors of the supporting system have Local Resource Gains (LROI) of 10 (10% loss) and the impact sensitivity is 20%, then the Total gain of the technology is

$$EROI_T = TROI\ (LROI\text{^}6 - \delta) \quad \text{or} \quad \underline{20}\ (.90\text{^}6 - .20) = \underline{6.6}$$

<u>The main variables are:</u>

ρ energy potential of resource; δ environmental impact sensitivity

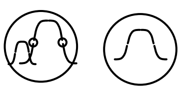
$EROI_T$ total amortized gain for using a technology accounting for all supports **EL** losses from all sources
EI energy used by technology = (**TP** people & commerce cost + **TT** technology cost +**TV** venture start & end cost)
ER returns from technology use, **PROI** technology resource gain, Local gains/losses of supports **LROI**'s
- If energy units are unknown for any support, use the 6000btu/$(2008$) applied to economic cost.

<u>Each variable:</u> includes **total embodied energy** of **goods, services, labor, money, info**

<u>Used to support:</u> the **Business, Technology, Environment, User, Culture, Investing.**

Note: This 'SimpleSysEROI' based on the 'totalEROI' model http://www.synapse9.com/issues/TotalEROI.pdf , adapting to the calculation model implied in the article: Chas Hall, Stephen Balogh, David J. Murphy 2009 "What is the Minimum EROI that a Sustainable Society Must Have?" Energies www.mdpi.com/journal/energies , abstr http://www.mdpi.com/1996-1073/2/1/25

Discussion (draft notes): To **Collect** resources**, Transform** them into products, then **Distribute** and **Use** them takes developing a whole system and operating its processes. Energy return on energy invested, **EROI = ER/EI,** or **'β'** , compares outputs to inputs of matching energy quality. If the energy output is only compared only to the direct energy input the comparison is valid if all their other energy costs and impacts are the same. The total ROI for any physical production process, includes all the embodied resource costs of developing, maintaining, operating and financing it too.



The timeline symbols refer to the input of venture capital (**EV**) and the development and aging of resources and techniques. Real investments tend to be made to initiate and stimulate the venture (**EV**) and returns by self-investment in the operations (**EO**) providing financial returns (**EF**). The usual objective is to develop an optimal level of **ER** to minimize other costs and accumulate enough financial return to do it again when resources are depleted or the system is outmoded. That "use it and move on" model of the hunter-gatherer method is itself becoming outmoded, of course, and finding a way to operate successions of technologies in a sustainable way is one of the reasons for looking at the details of whole systems and their whole resource investment life cycles.

ρ

When **ER** declines over time the diminishing returns can be reversed with increasingly costly technology. That may hide the change in the environmental responsiveness (goods, services, labor, money, info) corrected for constant technology quality. In practice that may be most conveniently estimated using the embodied and direct energy costs of the technology as a measure of quality, and compared to the resource returned, ignoring the profits. The idea is to isolate the physical performance of the resource and the physical performance of different technologies relative to each other, to consider their sustainability independent of the profits generated, which may be quite variable and distort the apparent sustainability of the long term investment strategy.