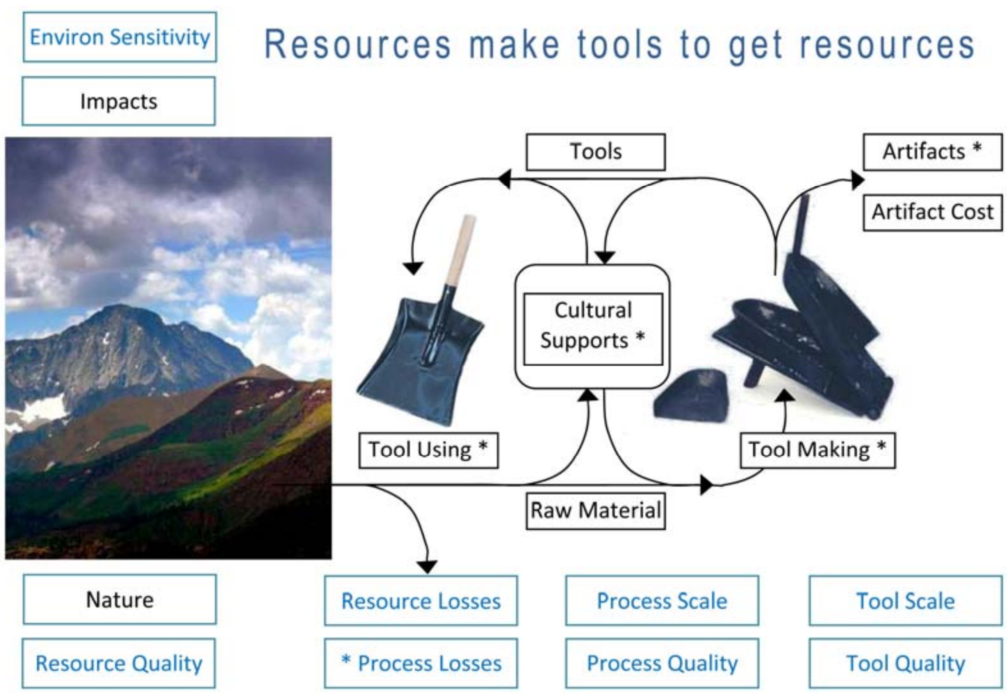
Calculating system **TROI**, combining **EROI** supply and user **UROI** overhead for a Whole Self-investment System, With development & opportunity costs for depleting resources

Self-investment systems tend to work as a whole, full of independently learning parts, with extensive histories and futures guided more by opportunistic effects of what the parts learn than the deterministic ones. Estimating the impacts of any one investment decision on the whole system it is part of is then an exercise in understanding how the environment will respond.

Following the graphic are two outline calculation methods for the true implied impact of individual investment choices on the whole system in which they are invested.

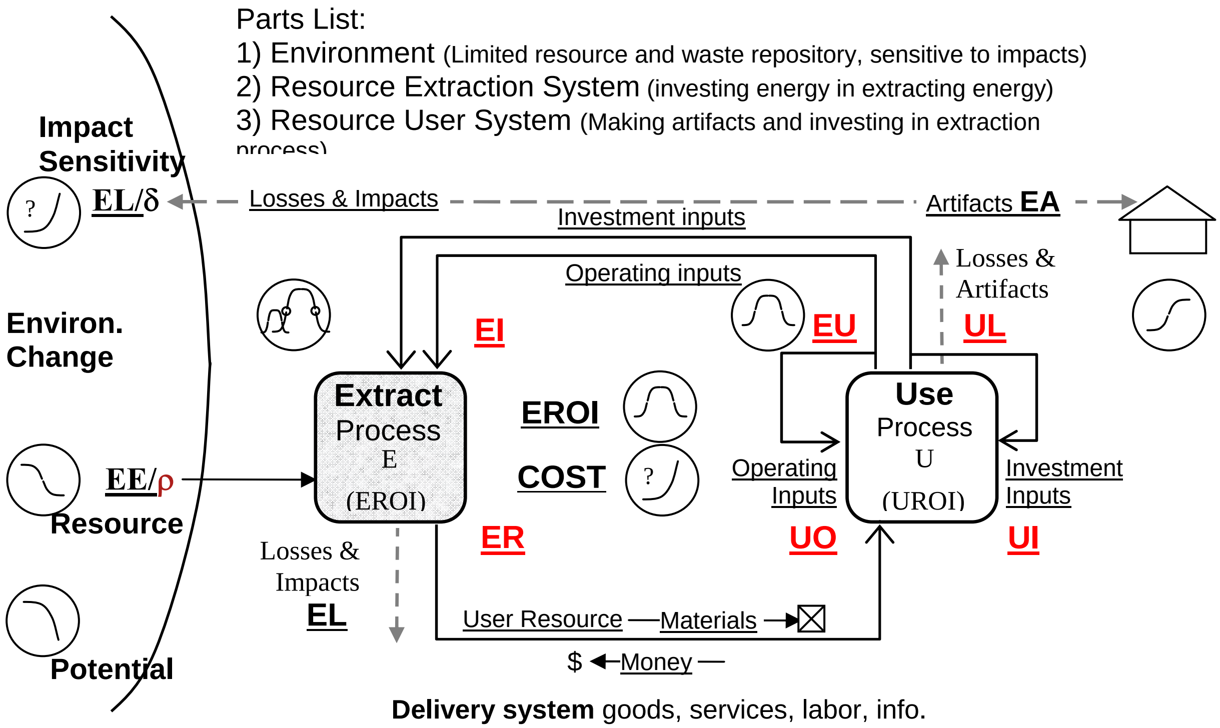
An economic system builds upon itself, making tools for expanding its tools
as it converts resources into wastes and artifacts, to then stabilize or exhaust itself

Graphic:



The Simplest Possible Model – Whole System **ROI**

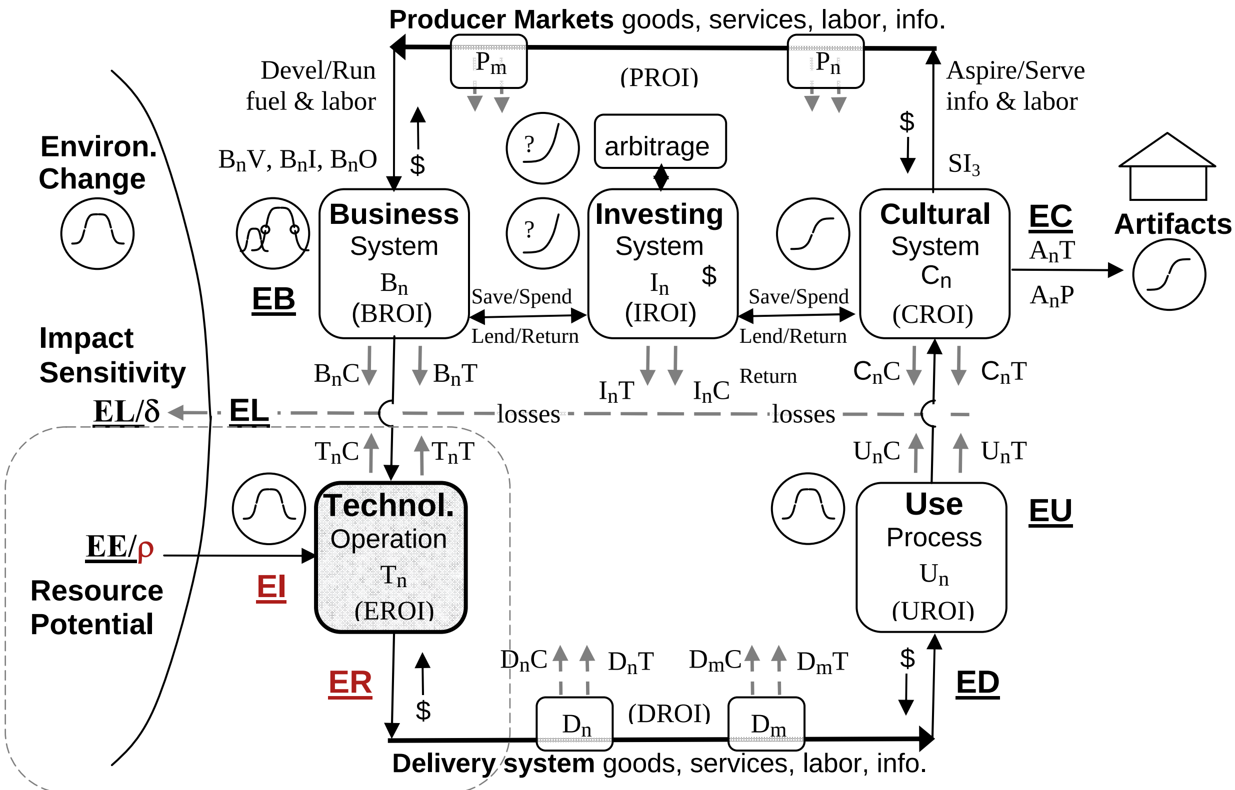
The whole resource development cycle (with timeline graphs in circles)



- Extraction Return on Inputs, **ROI > 1**   **EROI = ER / EI**
- Uses Return on Inputs, **ROI < 1**   **UROI = (ER-EU-UI-UO)/ER**
- Whole system Return on Resources   **TROI = EROI · UROI = (ER-EU-UI-UO) / EI**

As energy is accumulated in systems for resource extraction and use by self-investment, a natural resource first becomes easier to extract and then becomes harder to extract, with cost for increasing use eventually increasing without bound. Either resource depletion or the limits of perfection for the extraction process drive increasing cost. The share of the user resources to obtain resources first declines and then grows and squeezes out user processes that are not essential.

Whole System EROI – A general economic system model



- Resource Returns on Inputs, **ROI >1** — $EROI_r = ER / EI$
- Societal Costs on Inputs, **ROI <1** — $SROI = DROI \cdot UROI \cdot CROI \cdot IROI \cdot PROI \cdot BROI$
- Combined Return on Resources — $TROI = EROI \cdot SROI$ **(Return = 1/Overhead)**

The questions:

- Does the resource gain permit societal overhead growth or require streamlining to reduce it?
- How much of the earnings from a technology are needed to run it, and repay its development?
- How do you account for declining resource potentials & environmental impact sensitivity?
- Would alternate energy sources need to be subsidized by non-renewable resources?
- Is the potential of a natural resource falling below the sustainable level for supporting the system?

The basic idea for the model: 1)An easy way to account for whole system overhead costs and gains 2) using a way to mix exact and rough estimates for all unknowns, 3) find the EROI needed to break even and attract investment with a whole life cycle investment model, 6) in the interests of the culture.

The basic life cycle story: Each step moves energy and uses energy.
1) Starting with a seed resource from a prior surplus, 2) to start a business, 3) and operate a technology, 4) delivering products to other businesses, 5) serving users and the culture 6) which provide the labor and infrastructure for operating the businesses making useable resources, 7) a circle of roles with a net gain at one point of tapping nature for resources, and net losses at every other.

The basic equations are: $TROI = EROI \cdot SROI$, **if TROI falls below 1 subsistence fails**

- The total energy balance (**TROI**) combines the resource return on energy invested (**EROI**) and the collected costs & losses due to societal overhead for: Delivery chain, Use, Culture, Investment, Producer Chain, Business O&M: $SROI = DROI \cdot UROI \cdot CROI \cdot IROI \cdot PROI \cdot BROI$

- If Oil has a Gain (Return on Energy Invested) EROI of 20btu/btu, and 6 sectors of the supporting system have Local Resource Gains ($SPOI_i$) of 0.8 (20% losses each) then the Total gain of the technology is

$$\mathbf{TROI = EROI \cdot SROI_i\text{^}6 \quad or \quad \underline{20} \cdot (.70\text{^}6) = \underline{2.3}}$$

And so… in this example, a society still leavs a surplus of energy to be investing in <u>either</u> increasing overhead or decreasing dependencies, but close to crossing the threshold of 1.0 if the resource potential "ρ" declines.

Foreseeing the terminal decline "ρ" threatening the sustainability of societal overhead is the opportunity to switch investment from creating new overhead to sustainability.

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

ρ energy potential of resource; δ environmental impact sensitivity
TROI total amortized gain for using a technology accounting for all losses for all uses
EI energy costs = (current system cost **T** technology + **C** commerce +start & end costs **V** venture + **R** recycling)
ER returns from technology use, **EROI** technology resource gain factor
$SROI_i$ resource input loss factor, efficiency of resource use for each societal support system,

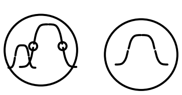
For each **EDelivered = ERreturned - (∑nT's + ∑nC's + amortized V's+ R's),** and **$SROI_i$ = ER/ED**
If energy use is unknown for societal supports use 6000btu/$(2008$), the global average energy intensity.

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

<u>Used to support:</u> the **Delivery chain, Use, Culture, Investing, Producer chain, Business O&M,**

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.