NOTE TO FILE:
Garvin H Boyle
Dated: 190506

On the Conservation of Energy in EffLab

Frontispiece

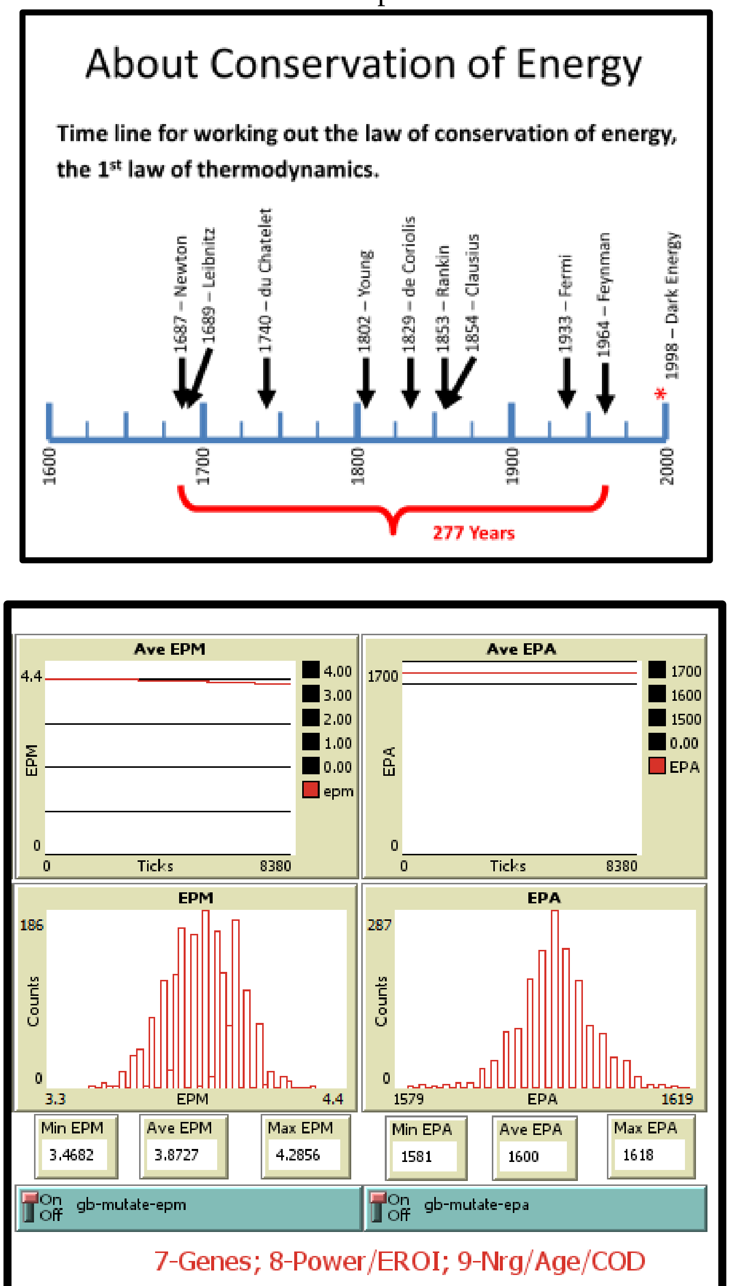


Table of Contents

1 - References

A. Telecon – Cao – Boyle, 190504
B. Cao Gaohang's questions
C. 190504 NTF Question From Cao Gaohang R1.docx.
D. EcoDyn P03 Conservation Effects G1.pptx
E. EffLab I model
F. SimEvo Model

2 - Background

Ref A is a teleconference using WeChat for which Cao Gaohang sent the Ref B questions.

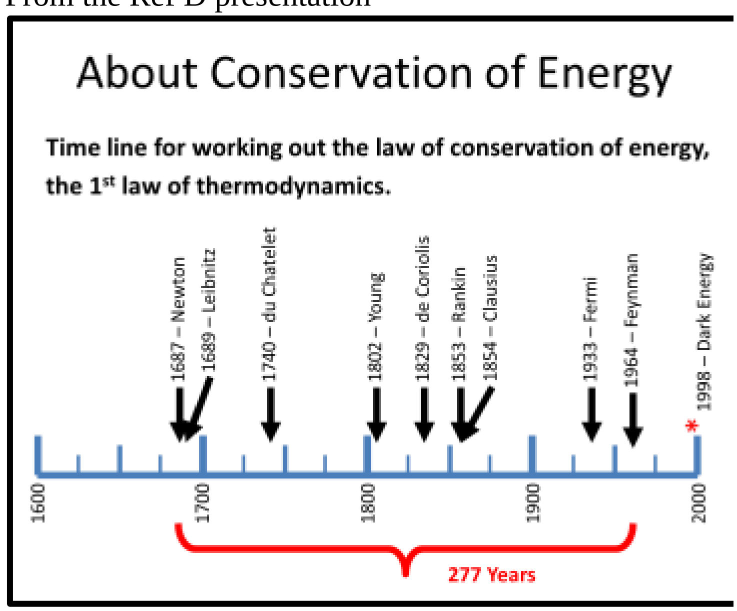
During the telecon Cao asked an extremely good question which is both important to answer and difficult to answer. I tried to answer it verbally, but it really requires a carefully written answer.
His question was "How can you prove that energy is conserved in Efflab?"

3 - Purpose

The purpose of this NTF is to give Cao Gaohang a written answer to his question.

4 - Discussion

From the Ref D presentation



My first answer is, you do not have to prove that energy is conserved in Efflab. I wrote it with the intent that the model EffLab would be consistent with the conservation of energy – a fundamental principle of thermodynamics.

But then it may be just a matter of semantics. How can I verify that energy is conserved in EffLab? In other words, I may have intended to be consistent with the law of the conservations of energy, but did I do it correctly? This question addresses "verification" of a model.

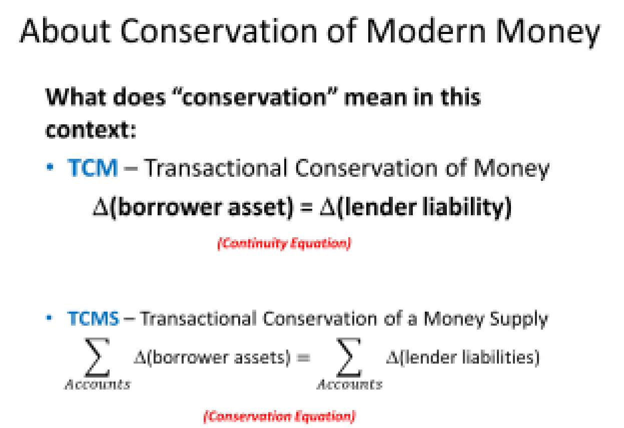
Cao pointed out that there is energy going in, coming out, and there is little meaning to the concept of "conservation" in this context. He has an excellent point.

At this point, I must try to explain the difficult concept of “conservation of energy”.

4.1 - Conservation of Energy – History

As per my time line shown above, taken from my Ref D presentation about the conservation laws, it took people about 300 years to figure out the details of the 1st law of thermodynamics – the Laws of the Conservation of Energy. It is NOT a simple concept.

From the Ref D Presentation



4.2 - Two types of equation

There are two types of equation about the conservation of energy. One is called the “continuity equation” and the other is called the “conservation equation”. You need to understand both.

In the context of the conservation of money, both equations mean pretty well the same thing. No money is created or destroyed in any transaction, or generally within the system. With money, as long as you agree that banks create all money in positive (credit) and negative (liability) form, the sum of money in a country or economy always adds up to the same number. It is possible that the sum of many positives and many negatives adds to zero.

Energy is a little different. It exists in many forms, and the many forms need to be converted to a common form (using conversion factors) before you can add them. And they are all positive, and only positive. For example, there are many kinds of kinetic energy, and many kinds of potential energy. You need to know the correct formulae to convert them all to some common form (say Joules) before you add them.

In an isolated economy (no money coming in or going out), the sum of all money does not change (if you accept my version of conservation of money). In a closed physical system the sum of all energy does not change. This is the meaning of the “conservation equation”. However, no economies are isolated, and no physical systems as isolated.

During a single financial transaction involving two financial agents, as money is transferred from one agent to another, the total money held by the two agents does not change, and the change in money held by one agent equals the negative of the change in money held by the other agent. This is the meaning of the “continuity equation”. This is true whether an economy is isolated or not isolated. That is why the “continuity equation” is important.

During a single energy transformation between two objects, as energy is transferred from one object to another, the total energy held by the two objects does not change, and the change in energy of one object equals the negative of the change in energy of the other object. This is similar to the conservation of money. This is true whether the system is isolated or not isolated.

4.3 - Model I, EffLab, and Conservation

In both models I have implemented conservation at the transactional level. This means that money (in Model I) and energy (in EffLab) are conserved in every transaction.

In Model I, conservation of money is also implemented at the system level because the total money in the system does not change.

In EffLab I have NOT implemented the conservation of energy at the system level, because it models a non-isolated system.

4.4 - The issue of EROI and ROI

The concept of EROI (Energy Returned On Energy Invested) is based on the continuity equation for the conservation of energy.

The concept of ROI (Dollars Returned On Dollars Invested) is based on the continuity equation, but only applied to positive money exchanges. Nobody talks about the "return on investment" associated with the debts that they owe to somebody. You talk about the interest payments. But, if somebody owes you money, that is your positive money, and you will talk about its ROI, the rate of interest you will receive.

The two performance ratios EROI (for energy) and ROI (for money) perform in a very similar fashion due to the continuity equation. Both are based on positive interpretations of the numbers.

It is this peculiar characteristic of the way both ratios are used **in practice** that allows me to use EffLab as a model of both ecological systems and economic systems. So, when I am interpreting EffLab I simply ignore the negative money. It is not in the model. It follows a different dynamic. This might seem like an egregious error (and, perhaps it is), but it does given some significant new insights, I think, into how ecological systems and investment systems operate.

It is also this peculiar characteristics (that EffLab only models positive money) that makes it appear to be similar to Model I. The dynamics of these two models are different because one (Model I) is only affected by rising entropy while the other (EffLab) is affected both by rising entropy, and also by rising complexity due to the effects of the MPP.

4.5 - The issue of quality

However, there is an additional issue when considering the conservation of energy that is not an issue with the conservation of money. Energy degrades when used, and is no longer useful. It is OK to have just as much energy as you had before, but if you cannot use it for anything, that is a problem. Money is not like this. You can use the same money over and over again.

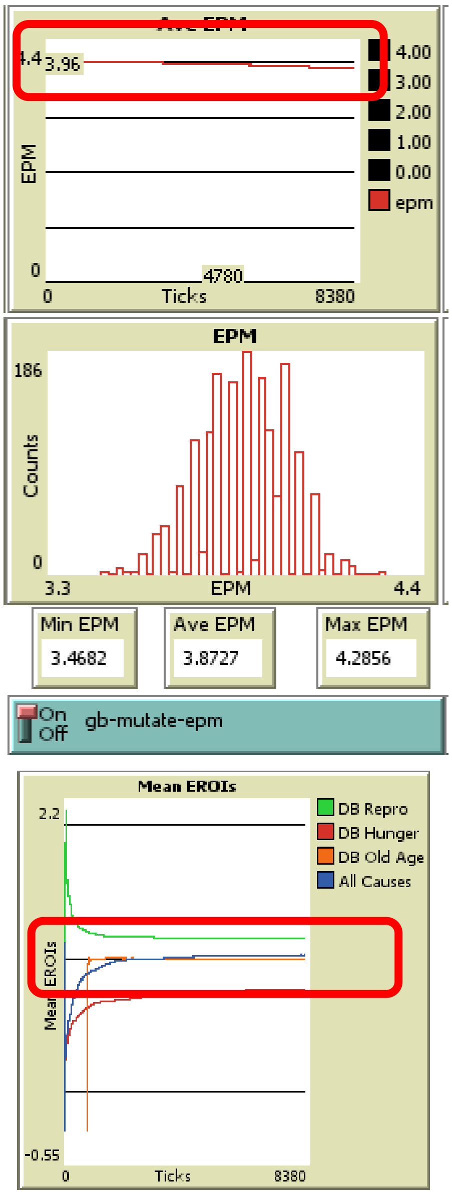
In Model I the same money cycles forever.

In EffLab the energy is used once, and discarded. EffLab needs to be open to reflect this.

Honestly, I do not know how best to explain the issue here. Quality of energy is a very difficult and controversial topic. This problem is closely associated with the second law of thermodynamics, and the appearance of thermodynamic entropy. If you study engineering or thermodynamics, there is a standard way to address it. But, it is not easy to understand without a good understanding of thermodynamics. It is also closely associated with the concepts of emergy, embodied energy, Gibbs free energy, and other similar but all slightly different presentations.

To the right is a set of related graphs from EffLab. EPM (energy per move) is the gene that controls the rate at which an agent degrades energy. This is analogous to the rate at which a financial agent spends money, largely because I am only modelling positive money, and I am not modelling debt. (To see a model in which I model both positive and negative money, you have to look at ModEco.) These graphs were taken at about 8,000 ticks in the standard run of the model. Notice that the average EPM is evolving to a lower value. This means that the organisms are becoming more effective at preserving the energy that they gather, in agreement with the Maximum Preservation of Energy Principle (part of the Maximum Power Principle). They are producing less thermodynamic entropy. This is the only window that I have into "thermodynamic entropy" in this model.

From the Ref E model - EffLab



But, compare that with the rising average EROI (All Causes – blue line) in the second graph. As the average EPM falls, the average EROI rises. This is not a surprise to me, but I have not yet explained how EROI and thermodynamic entropy might be related.

4.6 - Many Good Questions – Great Opportunity for Research

There are many questions about EffLab that I still cannot answer. Here are a few things to note:

- Entropy rises in Model I even though money does not degrade. The rising entropy is associated with the degradation of the system, as a whole, to self-organize and change its distribution of money.
- This same effect appears in Efflab, and I suspect that it is due to the degradation of the ability of the system to self-organize, but I am NOT AT ALL CERTAIN THAT THIS OPINION IS CORRECT.
- I have not modeled the degradation of either money or energy in EffLab, so I cannot and do not think that thermodynamic entropy is modeled there. But I do model the "single use" of energy, as opposed to the cyclic use of money, and so thermodynamic entropy might in fact appear in some fashion.

I think EffLab provides a great opportunity for an advanced student to do interesting research. But, they should have some knowledge of business, some knowledge of thermodynamics, and some knowledge of NetLogo programming.

4.7 - Connection EffLab to SimEvo

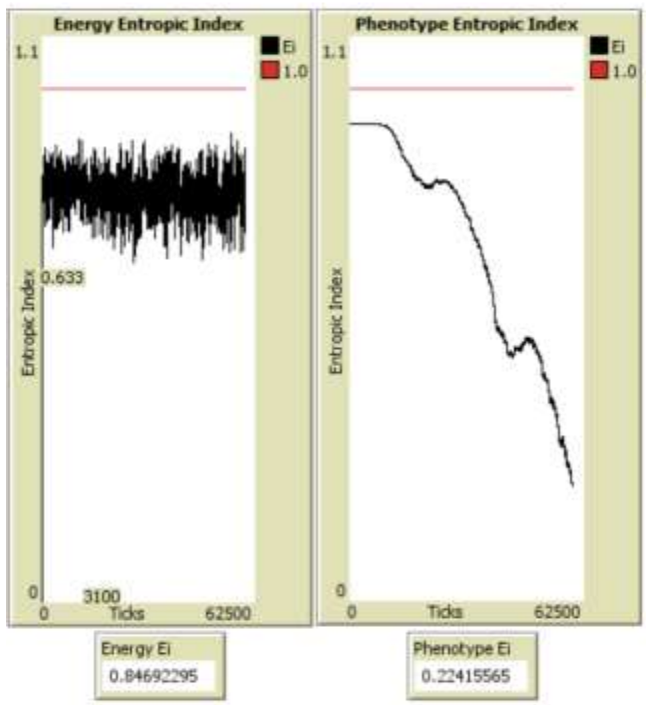
SimEvo is an implementation of Michael Palmiter's Simulated Evolution (1988).
EffLab is the same model.

The main difference is in the way data is aggregated and presented. One focuses on measuring EROI. The other focuses on measuring entropy.

I have not studied either model in any great detail, as I have done with ModEco and Model I. The detailed study of both EffLab and SimEvo are on my "To Do" list.

Here is a quick shot of the graphs about entropy from SimEvo.

From SimEvo



What this shows is that the entropy associated with the distribution of energy among the bugs quickly rose to a high level, and then remained there, just like it does in Model I of EiLab. However, the entropy associated with the improving ability of the bugs to find food (their rising complexity) falls as the population of bugs evolves. Evolution and the MPP are able to cause some entropy of the system to fall, even as the overall entropy of the distribution of energy rises. I have not yet had time to examine this effect in detail, or explain it in a note.   When I get time later, I may add these graphs to EffLab. The effect would be the same.