In and out have to equal: materials balance and the environment

Or what goes in must come out

Revised January 26, 2011

Lecture on *Materials Balance* -E.R. Morey -.wav file of a past lecture

Analysis of Environmental Pollution, Alan Kneese, *Swedish Journal of Economics*, 1971 - this article is a classic

Earth as a space ship, Kenneth Boulding, 1965 for other stuff by Boulding see http://www.colorado.edu/econ/Kenneth.Boulding/ Ken Boulding was a great economist and a member of this Department. He retired the year before I arrived at CU. He died a few years ago.

Pearce and Turner Chapter 2: The Circular Economy –David Pearce was a leader at the interface of environmental economics and ecology. He died recently, went to the hospital feeling sick and died a few hours later. See also David Pearce at Wikipedia

NPR: New antismog restrictions will increase global warming, 01/25/2010, audio at http://www.npr.org/templates/story/story.php?storyId=122626662&ps=rs

I have added my comments to these readings as pdf notes

Environmental economists have a way of thinking about the world that extends the way most other economists think about the world

(For your essay topics, if you are writing an essay, ask yourself whether materials balance is relevant.)

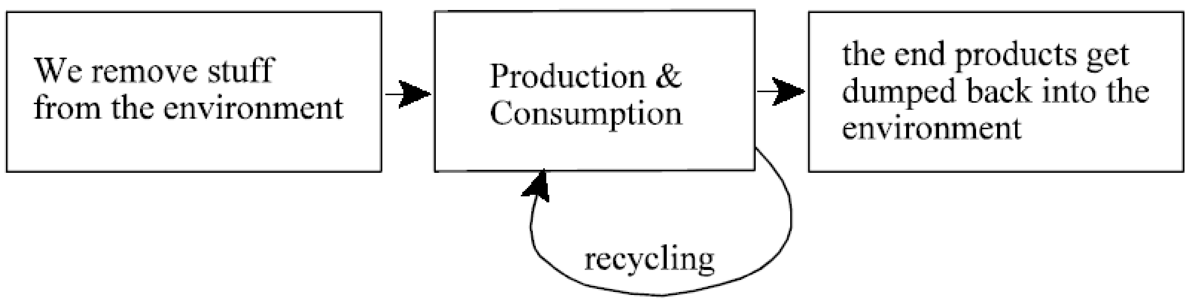
Environmental economists think of

(Production and consumption)

And

(Emissions, waste, and pollution)

as two sides of the same coin – what goes in must come out.



The total amount (weight) of what goes in must equal the total weight of what comes out. This is why it is called *Materials Balance*: in the long-run the environmental teeter-totter must balance.

This is because, with the exception of nuclear reactions, matter is neither created nor destroyed.1 (We need to learn a bit about the First and Second Laws of Thermodynamics.)

And,

If it doesn't come out in one form it must come out in some other form. Nothing is lost: production and consumption just change the form of things.

Everything that is produced and consumed has it origins in the environment. Think trees, plants, water, air, and minerals.

I think of production as simply a rearranging of stuff.

1 The same is true of energy. Google the First Law of Thermodynamics.

Energy is what drives the rearrangement.

Factories take inputs, rearranging them to produce an array of commodities.2 Some of these commodities are valued by consumers, or other producers, so can be sold for a positive price. Producing these “market” commodities is why the firm is in business. But other less desirable commodities are produced as well. The other commodities produced are called *emissions*, or more precisely, *non-market emissions* – one could think of goods as one type of emissions, the good type.

The total weight of the inputs used by the producer must equal the total weight of the market goods and other emissions generated by the production process.

I don’t know this for sure, but I suspect that in many production processes, the weight of the other emissions is much greater than the weight of the market goods produced. Think of how much of the material in a tree actually ends up in products consumed by individuals. The weight of the marble waste that was generated in the production of Michelangelo’s David probably weighed more than the David.

A lot of paper and cardboard ends up on your car floor after you have finished the Big Mac.

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2 In principles of economics courses, firms are presented as entities that produce a single product, a good. This is too simplistic. The “single product” firm produces vector of outputs, but only sells one of them. Many firms produce many products, and sell a subset of what they produce.

Copied from M. Bittman, Rethinking the Meat-Guzzler, NYT, Jan 27, 2008

Some emissions take up space but, other than that, cause little injury or harm. Other emissions cause injury. The injury can be as mundane as the unsightliness of a junk pile or couch in the front yard after the students have moved out, or life changing, as are birth defects caused by toxic chemicals.

The term *consumption* is also somewhat of a misnomer. Consider the plight of Big Macs – you don't have an anti-matter machine in your stomach. Consumption is, like production, just another rearranging of stuff. Consumers break down/rearrange the products they buy. In the case of Big Macs and bananas, the process is quick and obvious, less quick for marble statues.[3] Cars and stereos break down faster than statues but slower than Big Macs. Energy is what drives the process. The total weight of the materials you consume is not "consumed;" it just ends up in another form: respiration, fat, poop, couches in the front yard, trash.

It would be interesting to weigh everything you buy in a week (or month) and also everything you throw away or discard. Don't forget to weigh yourself as well. This could be the topic of an essay for the course.

The process of consumption makes me think of something written by Harry G. Frankfurt, a famous philosopher, writing on *bullshit*.

When we characterize talk as hot air, we mean that what comes out of the speaker's mouth is only that. It is mere vapor. …..

There are similarities between hot air and excrement, incidentally, which make hot air seem an especially suitable equivalent for bullshit. Just as hot air is speech that has been emptied of all of its informative content, so excrement is matter from which everything nutritive has been removed. Excrement may be regarded as the corpse of nourishment, what remains when the vital elements in food have been exhausted. In this respect, excrement is a representation of death that we ourselves produce and that, indeed, we cannot help producing in the very process of maintaining our lives. (*On Bullshit* by Harry G. Frankfurt, Princeton University Press, 2005.)

His article/book on bullshit got him on The Daily Show.

3 I recently learned through reading, not experimentation, that it takes, on average, about 50 hours to move stuff from mouth to butt, but there is wide variation across individuals. Alcohol speeds up the process. It also depends on whether something happens that "scares you shitless." See C.S.J. Probert, et al., Some determinants of whole-gut transit time: a population-based study, Quarterly Journal of Medicine 88, 311-315 (1995). And R. Bowen at **http://www.vivo.colostate.edu/hbooks/pathphys/digestion/basics/transit.html**

Recycling is another is another type of rearrangement of stuff: we take emissions that have no or little market value, and using energy, combine them with other stuff to produce commodities that have value to producers or consumers. The more we recycle, the more time it takes for the weight of the stuff we remove from the environment to equal the weight of the stuff that ends up back in the environment. Keep in mind that recycling is not free: it requires additional stuff and additional energy to turn waste into a valuable commodity.

Eventually, all the stuff that was taken from the environment for our needs ends up back there as our waste.

Why aren't we buried up to our necks in the waste of our ancestors: Julius Caesar's flip-flops, Benjamin Franklin's poop, and a whole lot of dead bodies?

The *assimilative capacity* of the environment

The environment has the ability, within limits, to break down and clean our waste, producing environmental commodities that we will eventually use as inputs to start again the whole process of production and consumption. This process of breaking down and renewing is driven by energy, typically from the sun (stuff rots in the hot sun). Some types of emissions are easier to break down than others; food and human waste break down pretty rapidly, toxic chemicals and nuclear waste can last a long time.

You paint or stain your house to decrease the rate at which it breaks down.

If, for example, one puts too much biological pollution in an environmental sink such as a river, the sink will be overwhelmed and lose it ability to assimilate the stuff. In the case of a river it will atrophy (die).

This holistic view of production and consumption has some important implications for environmental policy:

1. It is important to distinguish between emissions and pollution. Some emissions are neutral and some are bad, and some are "badder" than others. We call the bad stuff "pollution." Are any emissions good?

2. The only way to have zero emissions is to have zero production and consumption. Zero emissions are neither efficient nor equitable.

3. What is pollution abatement/reduction? Labor, capital and energy allocated to pollution abatement does not make the pollution disappear. The process converts the pollution into a less harmful form—we can't make matter disappear. Pollution abatement is a process of transformation not a process of elimination.
(Consider a refinery smoke stack with and without scrubbers. What happens to the waste? Find some sources and examples)

4. Recycling waste into useful stuff requires that energy and scarce resources be allocated to recycling. E.g. paper waste does not magically convert itself to recycled paper. If we could costlessly convert bads into goods, we always would.[4]

5. Society can reduce pollution by reducing production and consumption.

6. Society can reduce pollution by increasing recycling, but this requires additional inputs and energy.

7. Society can reduce pollution by converting bad emissions into less bad emissions. Again, this takes energy.

8. Given the state of technical knowledge, and assuming efficiency in production and full employment of resources, can society hold production, consumption and recycling constant and reduce overall emissions? NO. Possibly yes if current production processes are inefficient.

9. Given the state of technical knowledge and assuming efficiency in production, can society hold production, consumption, and recycling constant and reduce pollution? Maybe? It requires that there is unemployed labor, capital, and energy, and that some of it be allocated to converting pollution to less damaging forms. That is, total emissions would remain constant but we would change their composition.

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4 I worked for years on a legal case about PCB pollution in the Bay of Green Bay, a large bay on Lake Michigan. The PCB pollution was the result of recycling: PCBs were used to remove the ink from newsprint.

What are the implications of materials balance for environmental policy?

Think about how we dispose of our wastes; it must be emitted either into the air, the water, or dumped on the land. We could shoot it into outer space, but that would require a great deal of energy.

What will happen if we decrease air pollution holding production, consumption and recycling at their current levels?

Environmental policy should not consider different types of pollution in isolation. They are all different forms of the same thing, so cannot be correctly managed in isolation of one another.

If we pass a law that requires firms to reduce air pollution they will likely respond by producing more water pollution and solid-waste pollution: it has to go somewhere.

The environmental issue is often not so much one of reducing emissions but rather deciding on the mix of pollution/emissions that is efficient and equitable. There is also the question of where the emissions occur, and the question of how and where the wastes are stored. In the backyards of poor people?

Further thoughts:

The materials balance is an implication of the First Law of Thermodynamics, which is typically defined in terms of energy rather than matter.

http://en.wikipedia.org/wiki/Main_Page says

> The first law of thermodynamics, a generalized expression of the law of the conservation of energy, states: the increase in the internal energy of a system is equal to the amount of energy added to the system by heating, minus the amount lost in the form of work done by the system on its surroundings.
>
> Description:
>
> The essence of the First Law of Thermodynamics declares: energy cannot be destroyed. The first law of thermodynamics basically states that an isolated thermodynamic system can store or hold energy and that this internal energy is conserved. Heat is a process by which energy is added to a system from a high-temperature heat source, or lost to a low-temperature heat sink. In addition, energy may be lost by the system when it does mechanical work on its surroundings, or conversely, it may gain energy as a result of work done on it by its surroundings. The first law states that this energy is conserved: The change in the internal energy is equal to the amount added by heating minus the amount lost by doing work on the environment. ………..

Think of the earth, which is not a closed system: energy is lost to space and energy is absorbed from the sun. If more is absorbed from the sun than is lost to space, earth increases in temperature. That is called global warming.

Searching http://www.physlink.com/Education/AskExperts/

> Question
>
> What is a simple definition of the laws of thermodynamics?
>
> Answer
>
> Thermodynamics is the study of the inter-relation between heat, work and internal energy of a system.
>
> The British scientist and author C.P. Snow had an excellent way of remembering the three laws:
>
> 1. You cannot win (that is, you cannot get something for nothing, because **matter** and energy are conserved).
>
> 2. You cannot break even (you cannot return to the same energy state, because there is always an increase in disorder; entropy always increases).
>
> 3. You cannot get out of the game (because absolute zero is unattainable).

So, what does all this have to do with Materials Balance? I am not quite sure, but I think it goes something like this. "Matter" is made up of energy – remember the old $E=MC^2$. But the only way to turn the matter into energy is with a nuclear reaction. So, absent nuclear reactions, matter is conserved. Burning coal and wood, in contrast, does not convert matter into energy, the total weight of the stuff burned just goes up in smoke – energy in the wood is just released. Hope this description is close to correct.

We should also note that along with Materials Balance there is *Energy Balance*. Energy is neither created nor destroyed. This balance also has important implications for production, consumption and the environment.

When we use energy – the driving force in the rearrangements of production and consumption – the energy used is not lost, rather it is dissipated/entropied. That is, it is converted, from our perspective, into a less-useful form. This process of dissipation is why we cannot have a perpetual-energy machine. This is the gist of the Second Law of Thermodynamics.

http://en.wikipedia.org/wiki/Main_Page says

> Second law of thermodynamics
>
> The second law of thermodynamics, in a concise form, states that "the total entropy of any thermodynamically isolated system tends to increase over time, approaching a maximum value.

General description

In a general sense, the second law says that the differences between systems in contact with each other tend to even out. Pressure differences, density differences, and particularly temperature differences, all tend to equalize if given the opportunity. This means that an isolated system will eventually come to have a uniform temperature. A thermodynamic engine is an engine that provides useful work from the difference in temperature of two bodies. Since any thermodynamic engine requires such a temperature difference, it follows that no useful work can be derived from an isolated system in equilibrium, there must always be energy fed from the outside. The second law is often quoted as the reason that we cannot build perpetual motion machines. ……

While the earth is effectively a closed system with respect to materials (at least until we start mining the moon), it is not closed with respect to energy.[5] The sun is an outside source. Dissipated energy can be pollution; think noise and unwanted heat.

Can we recycle energy?

Yes, but every time we recycle the same energy, we get less useful energy (the recycled energy is not as a productive from our perspective; it is more difficult to harness)

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5 Meteors sometimes arrive from outer space.