OSU~EmEa – 6

Static Emergy Accounting

Emergy algebra, Emergy evaluation procedure , Static calculation

Emergy Algebra...

Six general rules for allocating emergy within systems of processes….

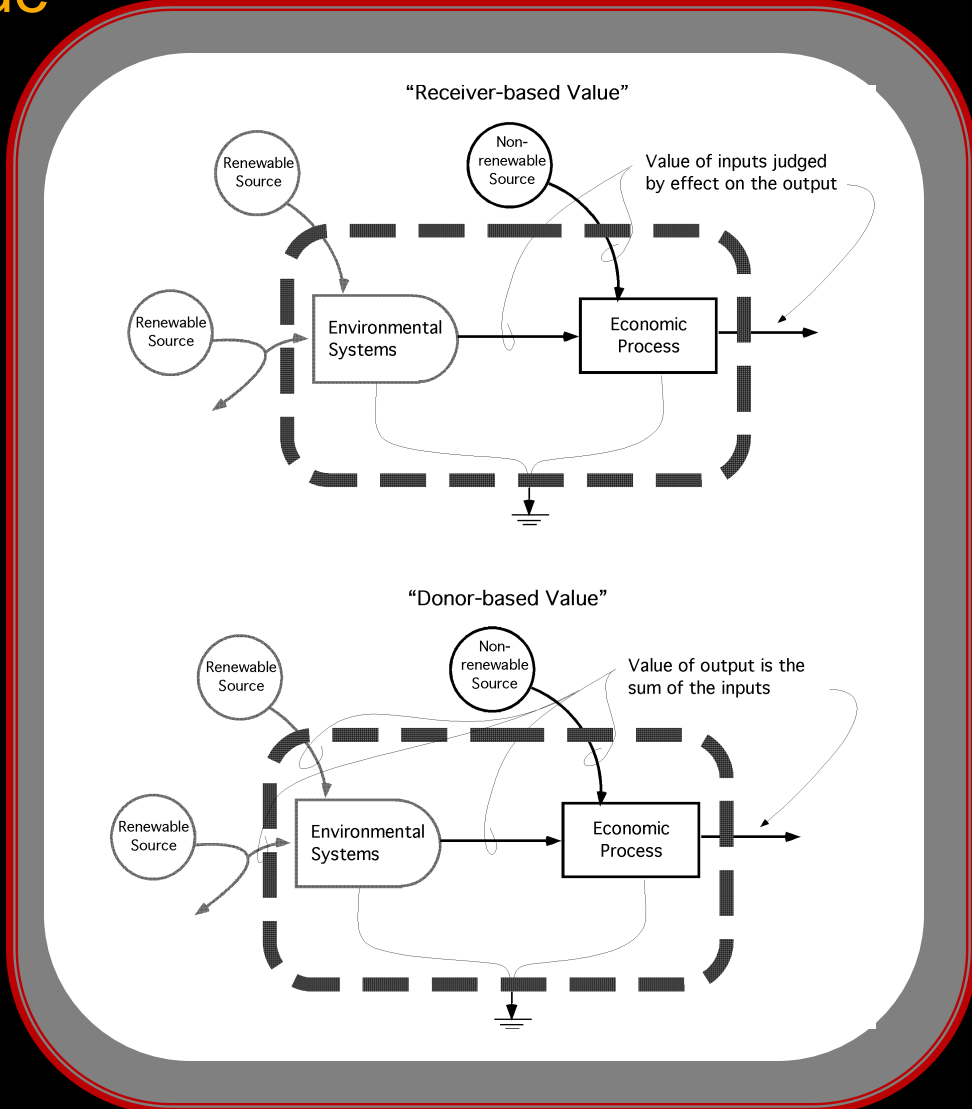
and some interesting theoretical observations

Value Systems...

Donor Value vs. Receiver Value

Receiver Value = Utility theory of value....Classical economic value theory. "Willingness to pay"

Donor Value = Supply side perspective...what goes into something determines its value



Emergy Algebra...

Under a steady state assumption there are some general rules or accounting procedures that we have collectively called *Emergy Algebra* (Odum, 1996).

The rules are used to assign emergy to flows of energy, materials, and information within systems.

The first four rules describe how to assign emergy to outputs including splits and co-products.

The fifth rule deals with double counting a special issue in static emergy algebra to insure that feedbacks, recycle and co-products are treated correctly to avoid double counting.

The sixth rule pertains to by-product flows

Emergy Algebra...

In describing the rules mathematically, the following notations are used...

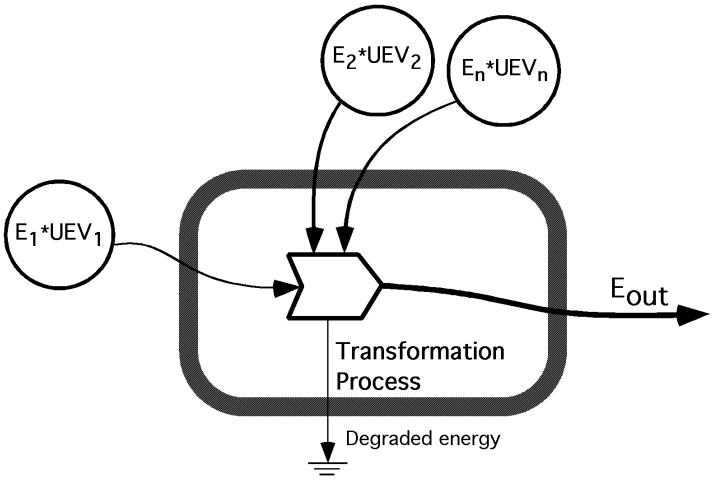
$\mathbf{u_i}$ = i^{th} input flow, used
$\mathbf{Y_i}$ = i^{th} output flow
$\mathbf{E_{(u_i)}}$ = available energy of the i^{th} input, used
$\mathbf{E_{(Y)_i)}}$ = available energy of the i^{th} output,
$\mathbf{Em_{(u_i)}}$ = emergy of the i^{th} input,
$\mathbf{Em_{(Y_i)}}$ = emergy of the i^{th} output,
$\mathbf{Tr_i}$ = transformity of i^{th} flow or product,
$\mathbf{Sp_i}$ = specific emergy of i^{th} flow or product,
$\mathbf{UEV_i}$ = unit emergy value of i^{th} flow or product, and
$\tilde{\Rightarrow}$ = "assigned to"

Rule #1 – Definition of emergy

Emergy is the available energy (exergy) of one kind that is used up in transformations directly and indirectly to make a product or service.

The emergy of the output is equal to the sum of the inputs multiplied by their UEVs

The UEV of an output is equal to the emergy of the output divided by the energy or mass of the output.



$$Em_{out} = \sum_1^n E_i * UEV_i$$

$$UEV = Em_{out} / E_{out}$$

Where;

$E_{1...n}$ = Available energy inputs

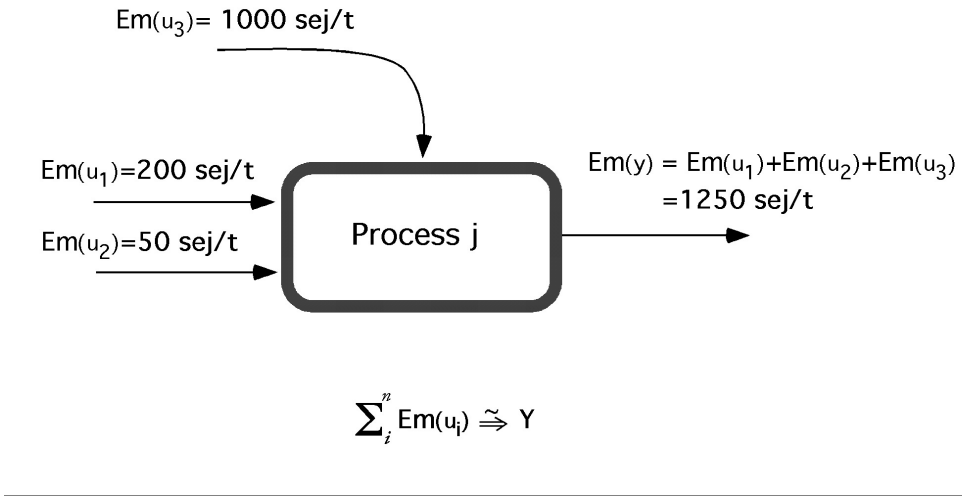
E_{out} = Available energy of the output

Em = Emergy

UEV = Unit Emergy Value

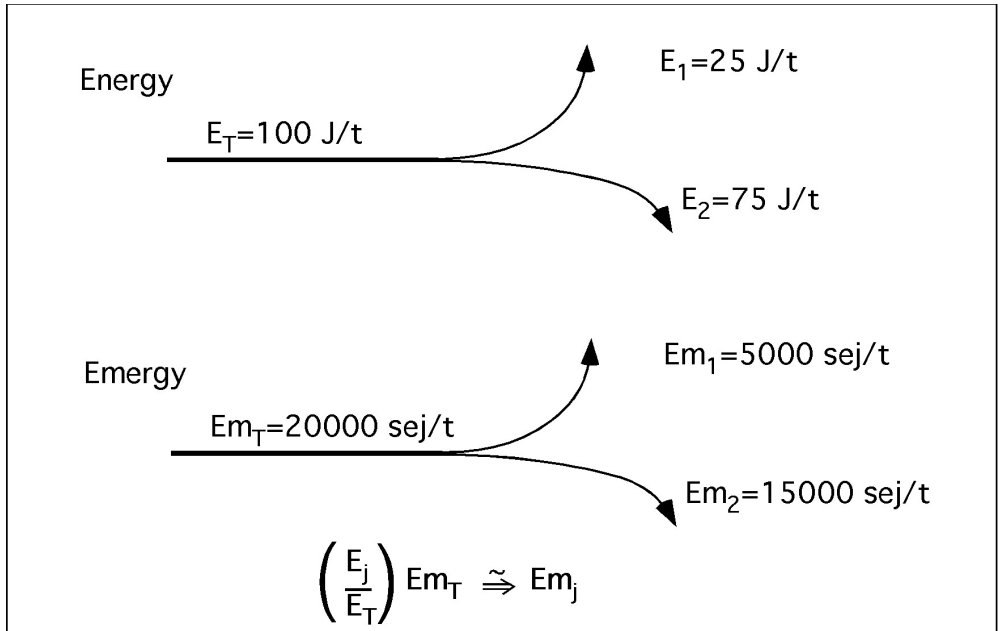
Rule #2 – Assigning emergy to transformation outputs

In processes having one output, all independent emergy inputs are assigned to the processes' output.



Rule #3 - Splits of the same material or energy...

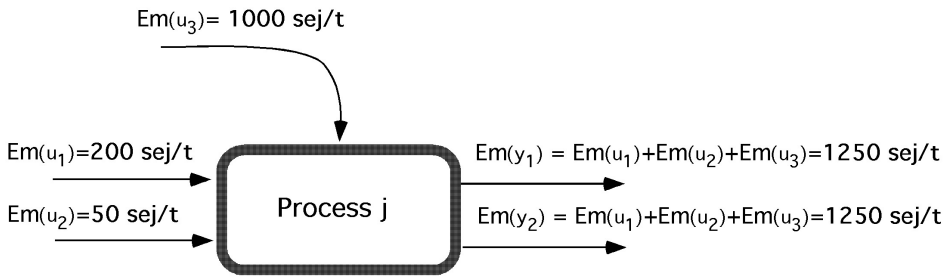
When a pathway splits, the emergy is assigned to each branch of the split based on its percent of the total available energy flow (or mass) on the pathway before the split.



Rule #4- Co-Products...

In processes having two or more co-products, all independent input emergy is assigned to each co-product.

A co-product is a product that is produced jointly with another product



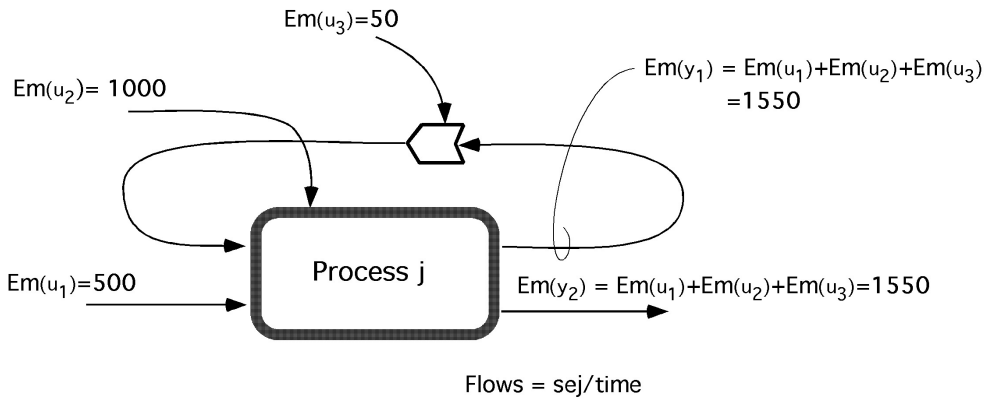
$\sum Em(u_i) \tilde{\Rightarrow} \forall Y_i \in \{Y_1, \ldots Y_n\}$

$\forall$ = to all
Y_i = i^{th} co-product
$\in$ = belonging to the set

Rule #5 – Double counting...

Within a system, emergy cannot be counted twice:

- *emergy in feedbacks cannot be double counted*
- *co-products, when reunited cannot be added to equal a sum greater than the source emergy from which they were derived.*



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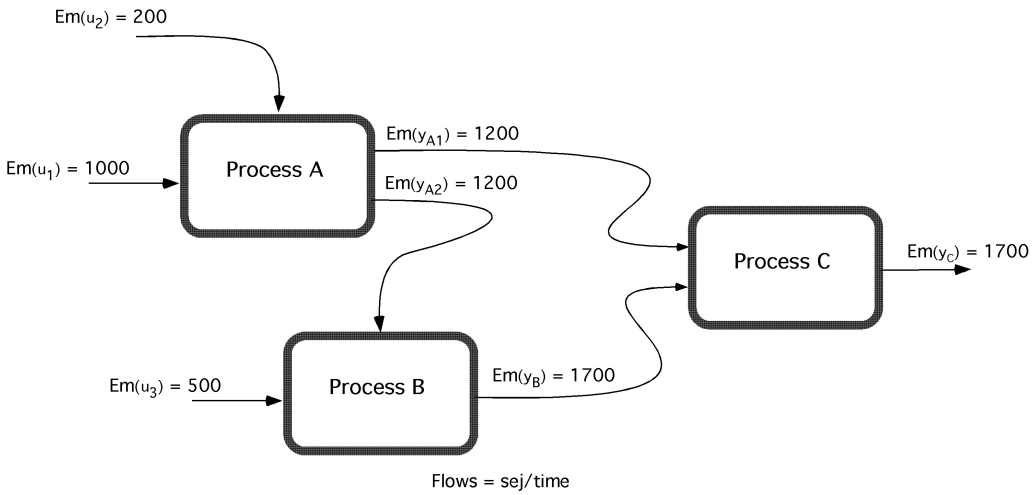
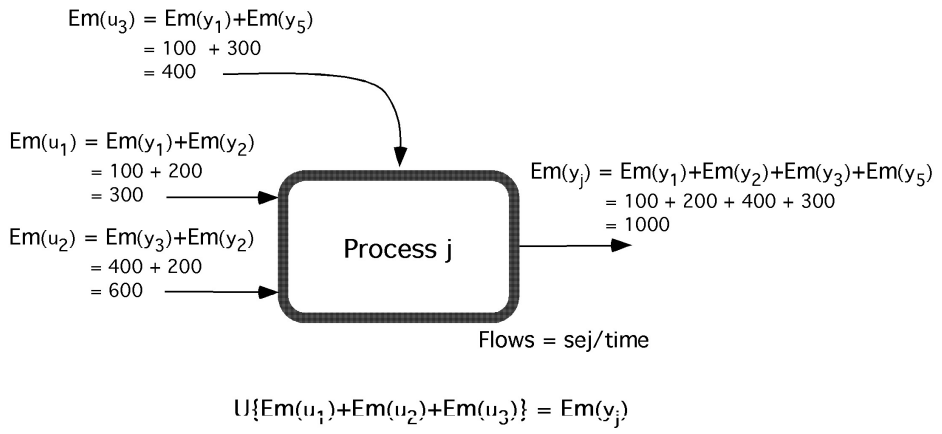


Rule #5 – Double counting (continued)...

Only those emergy flows which make up inputs $Em(u_1)$, $Em(u_2)$, and $Em(u_3)$ that are distinct and independent are included in the output, $Em(y_j)$.



Rule #5 – Double counting (continued)...

Set theory has a convenient way of denoting concept of independent flows using the union (∪) operation.

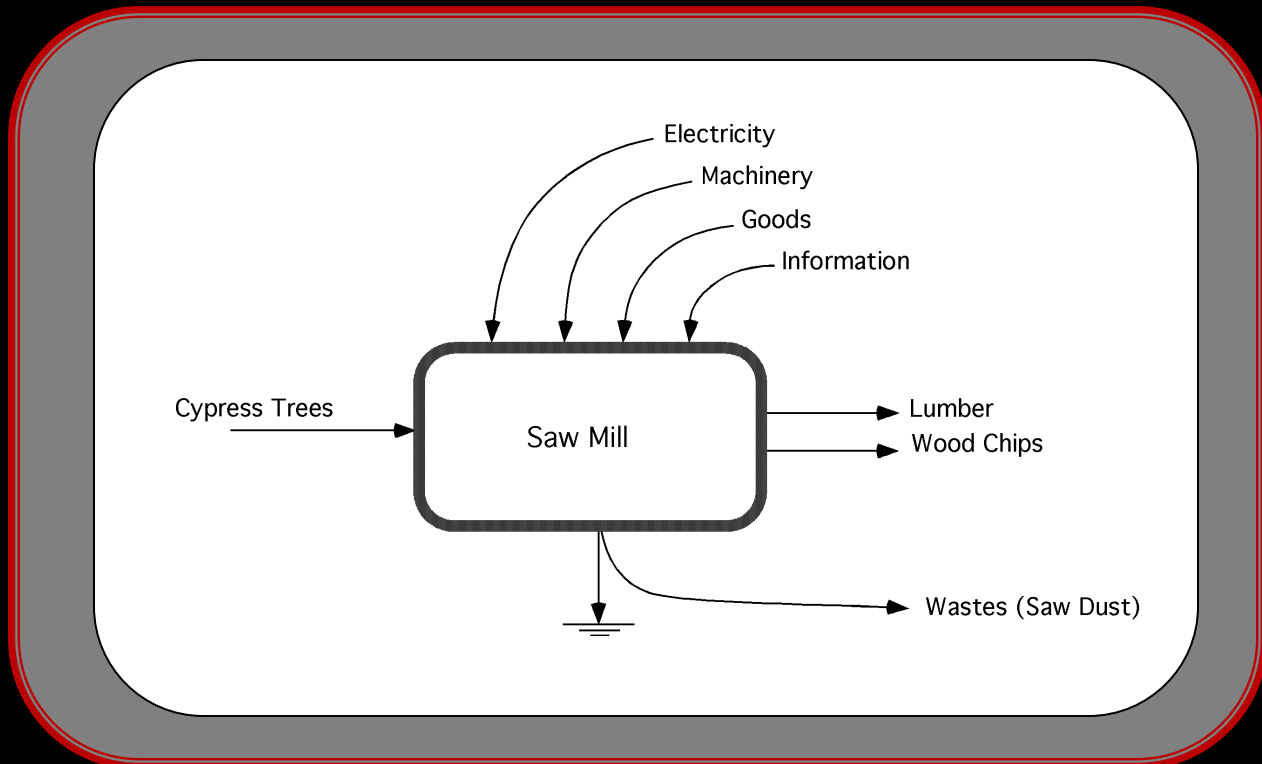
The union (∪) of a collection of sets is the set of all distinct elements in the collection.

For instance the union of the two sets {1, 2, 3} and {2, 3, 4} is {1, 2, 3, 4}. Only the elements of the two sets that are distinct are represented by their union.

$$\bigcup \left\{ Em(u_1), Em(u_2), Em(u_3) \right\} = Em(y_j)$$

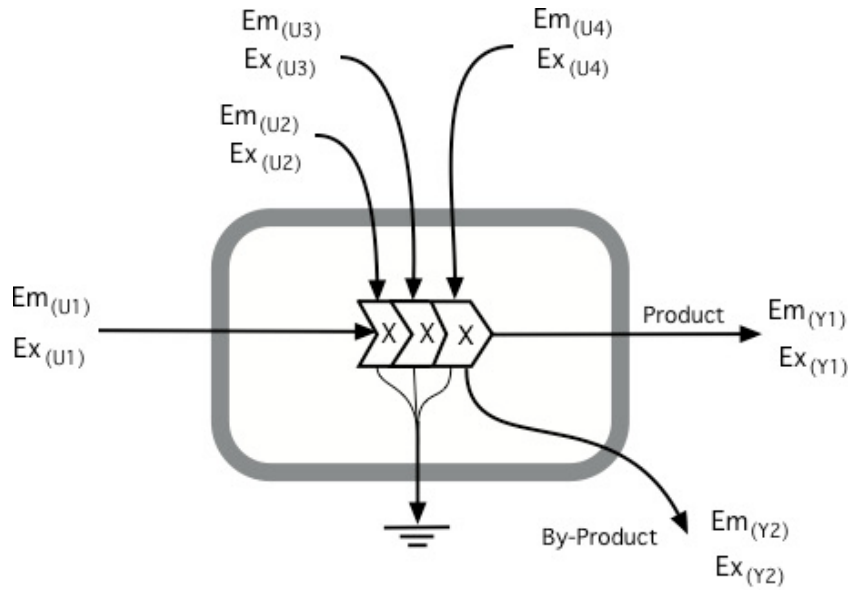
Co-products vs. By-products

Co-products are products that are jointly produced and are up grades of the inputs, while a by-product is an incidental output (an output that is a down grade of the inputs).



Rule #6: By-product flows…

A by-product is an incidential material or energy produced in a process that is a degraded form of the inputs

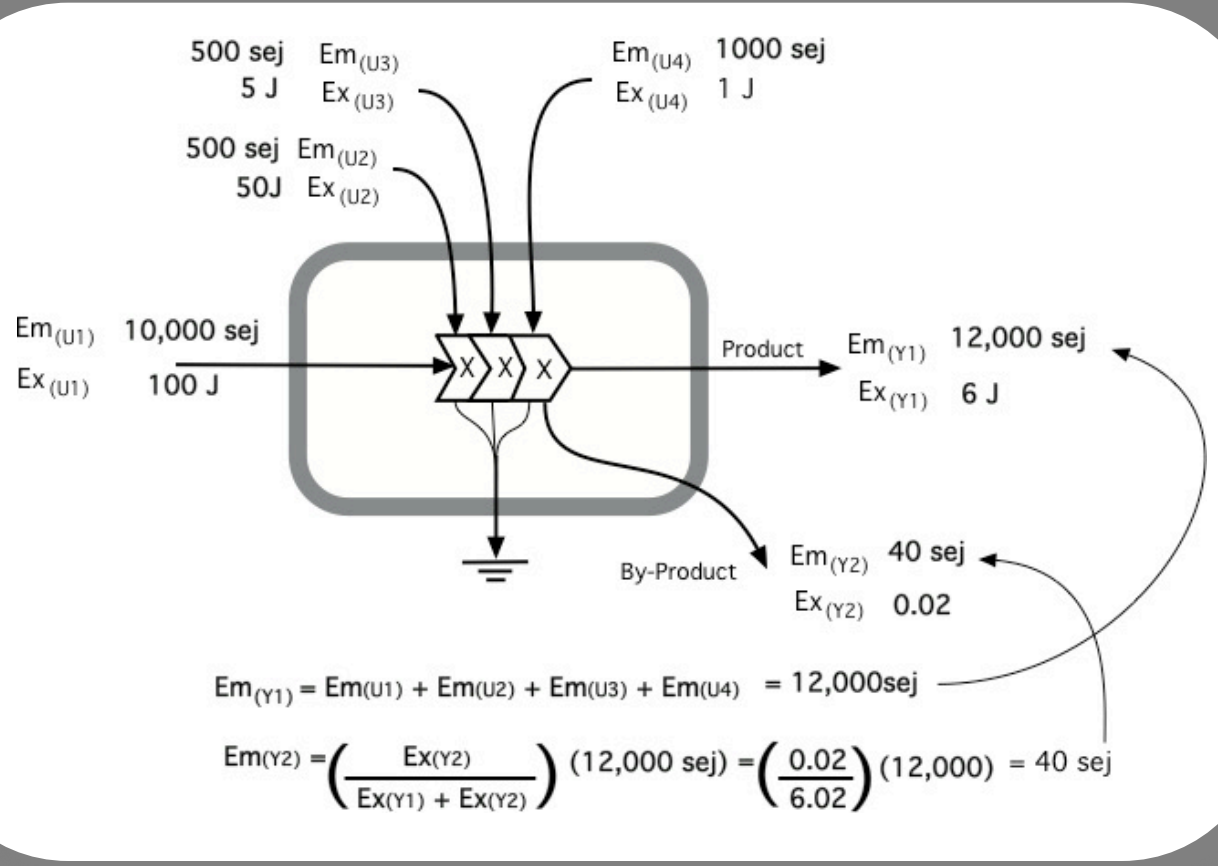


$$Em_{(Y1)} = Em_{(U1)} + Em_{(U2)} + Em_{(U3)} + Em_{(U4)}$$

$$Em_{(Y2)} = \frac{Ex_{(Y2)}}{Ex_{(Y1)} + Ex_{(Y2)}} \left(Em_{(Y1)} \right)$$

Rule #6: By-product flows…

The emergy of the by-product flow is assigned based on the percentage of the total exergy that is the exergy of the by-product flow



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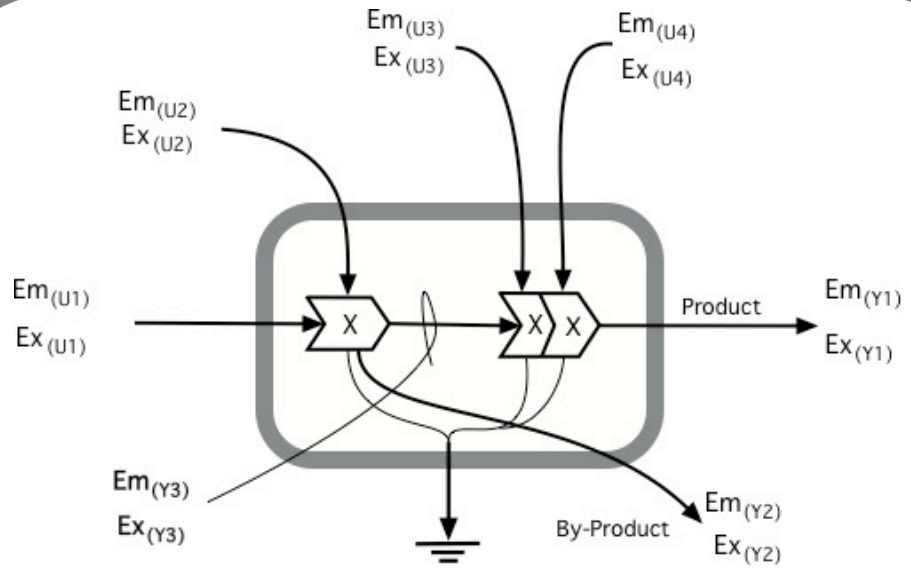

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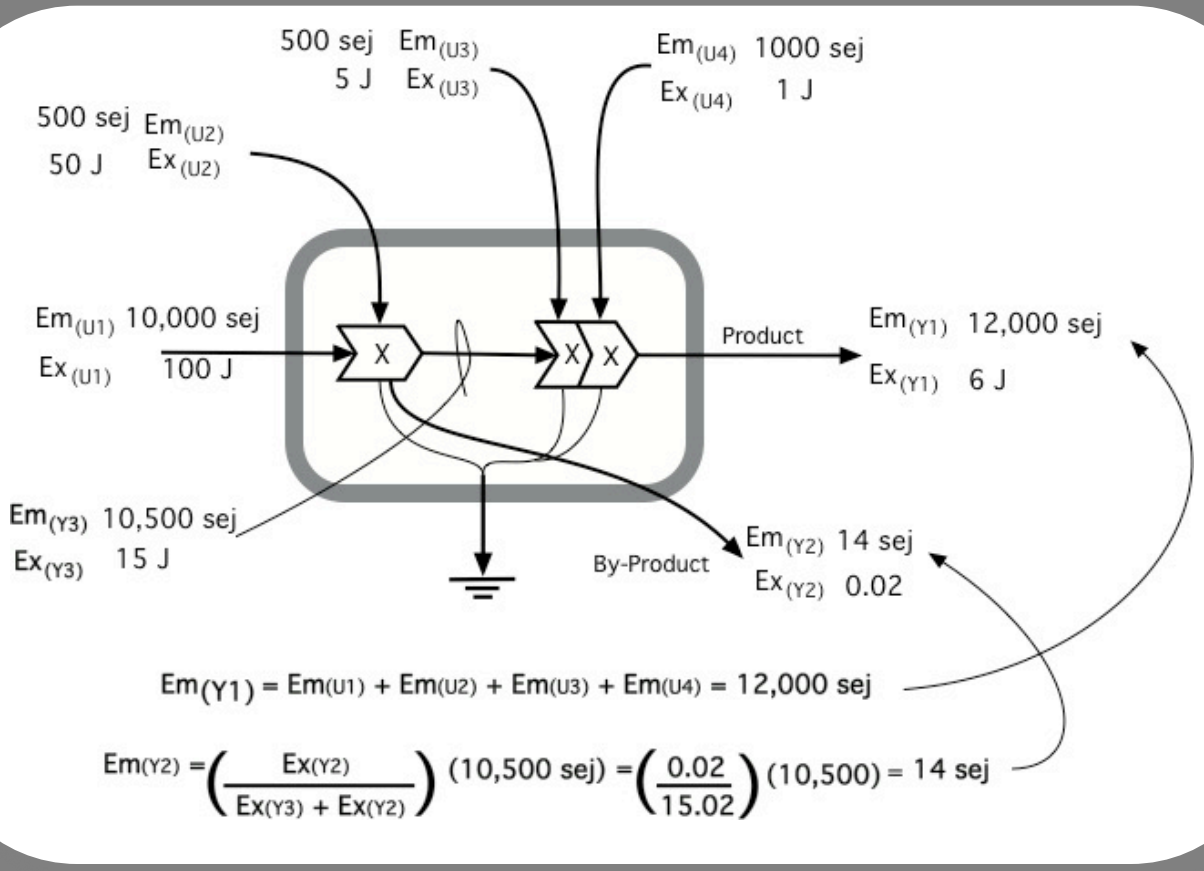


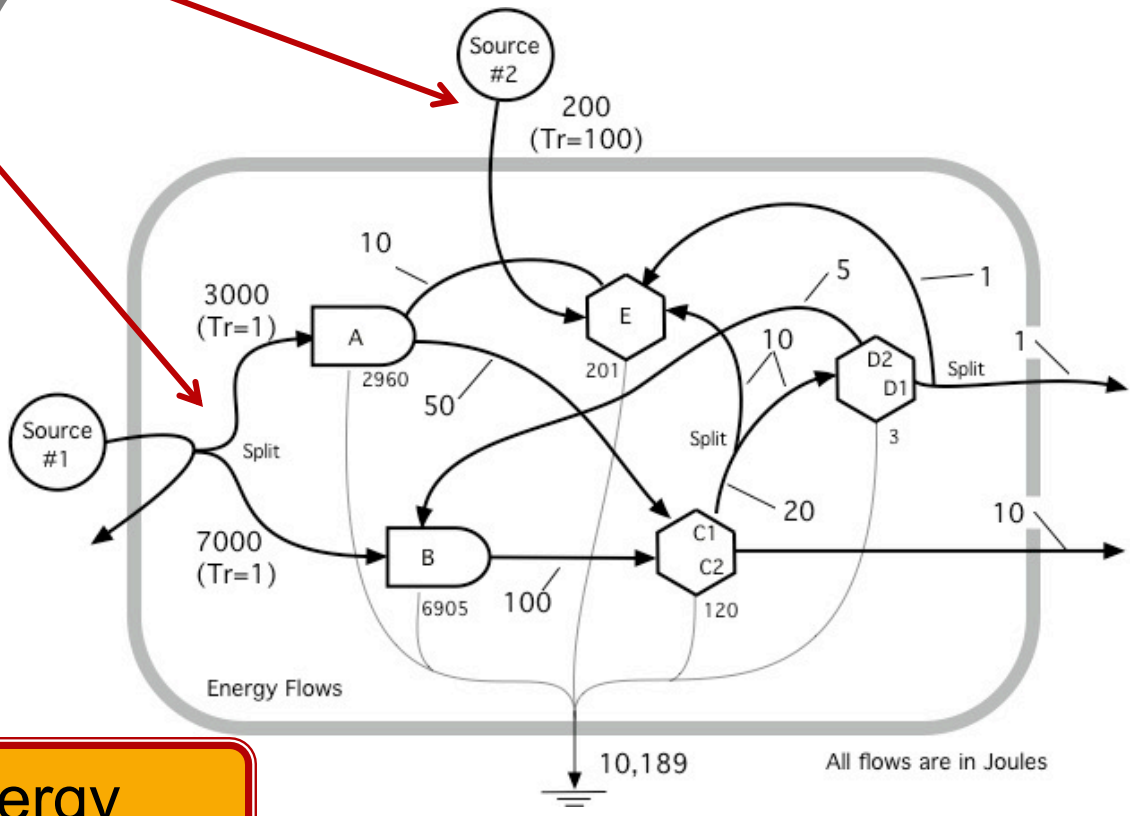
Emergy Algebra...

UEV = 100 sej/J

UEV = 1 sej/J

A more complex system example

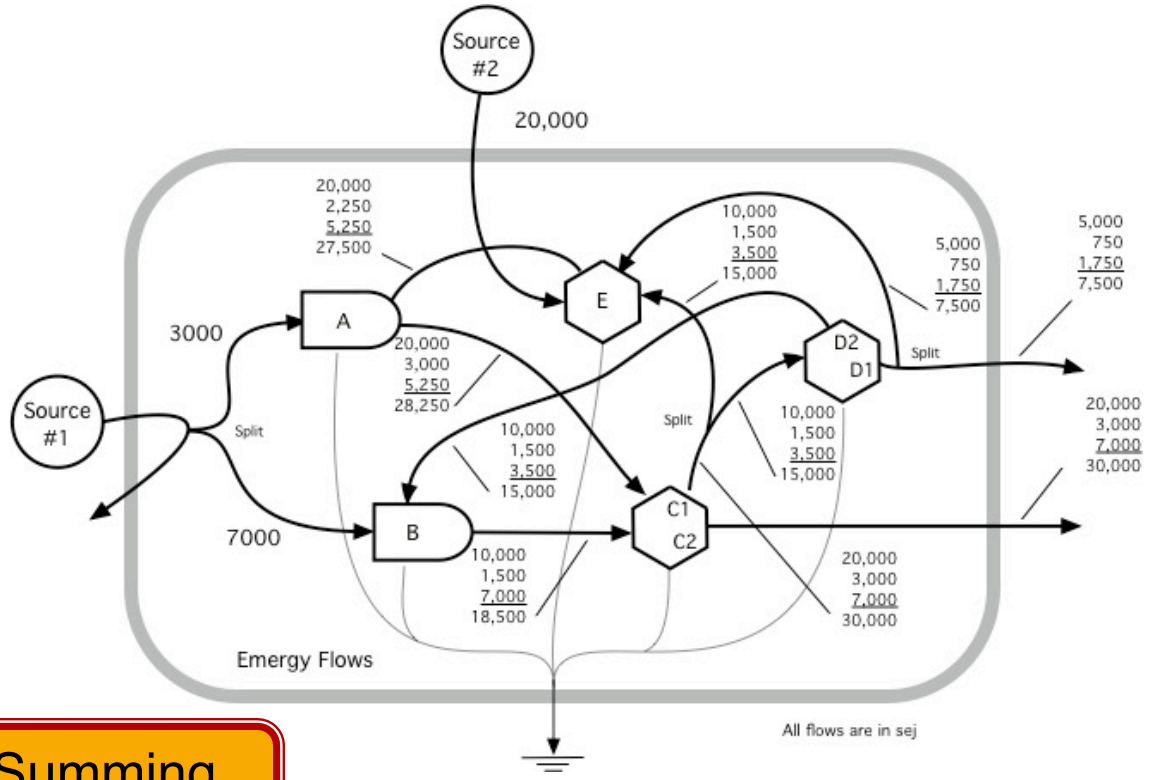
…Splits, co-products, and "doublecounting"



Energy

Emergy Algebra...

Track-Summing Method
- Track each source, in turn, and then sum the emergy input to each component

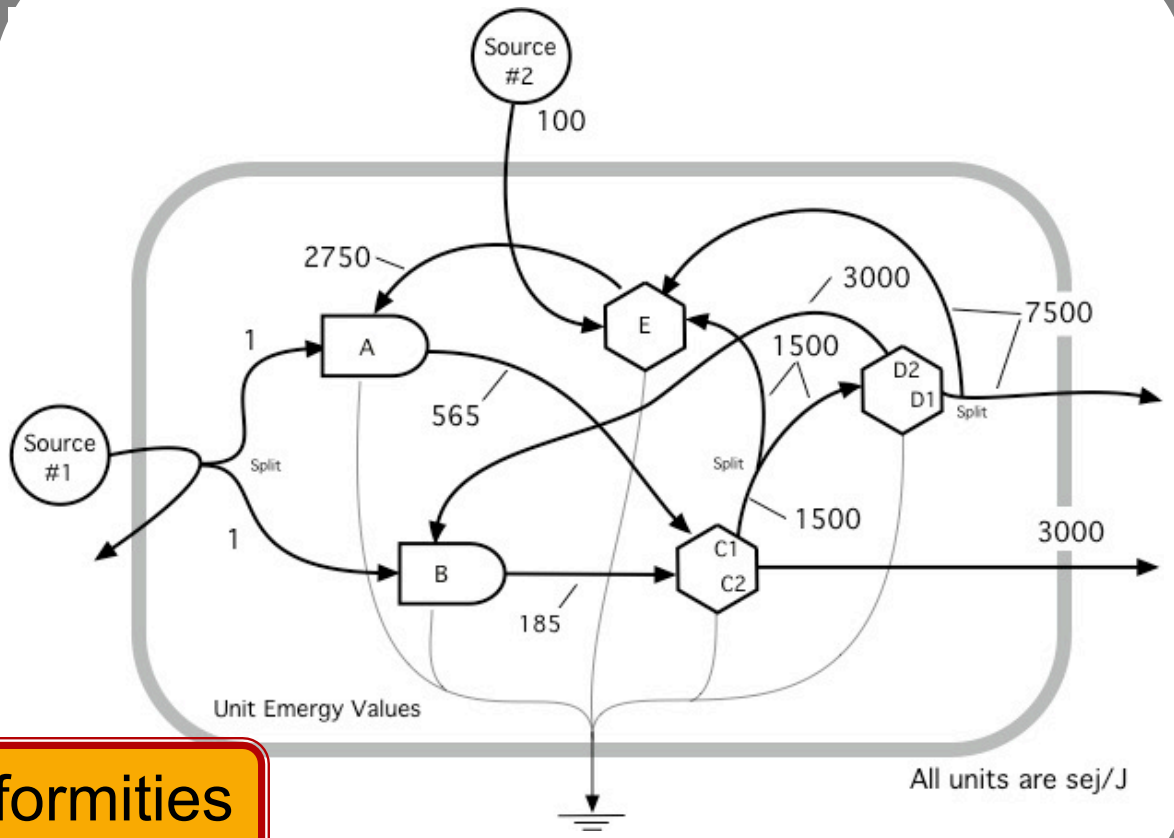


Track Summing

Emergy Algebra...

Resulting solar emergy transformities

(Divide the emergy on each pathway by the energy)

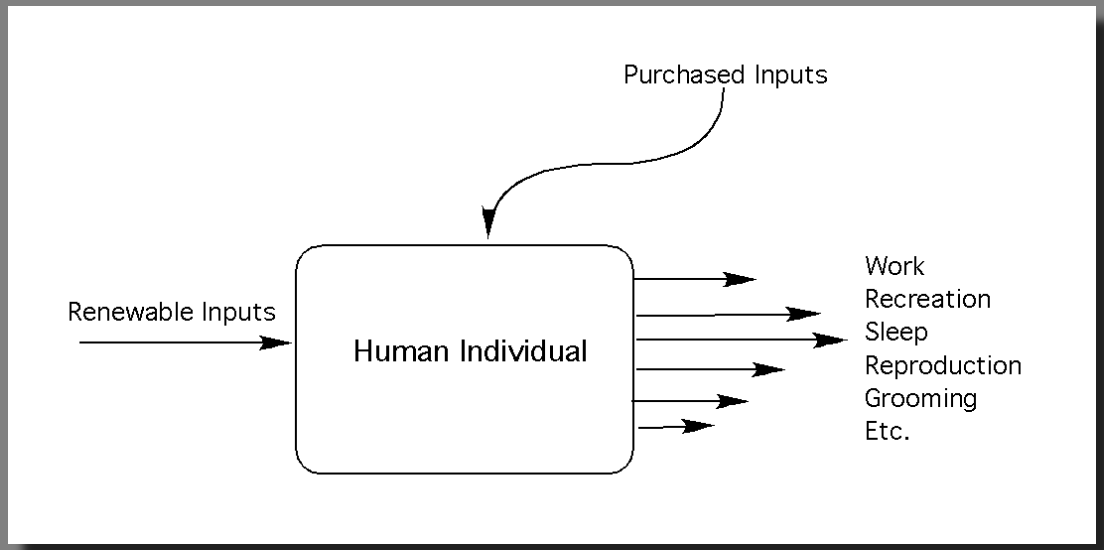


Transformities

Theoretical Consideration…

Human co-products and by-products

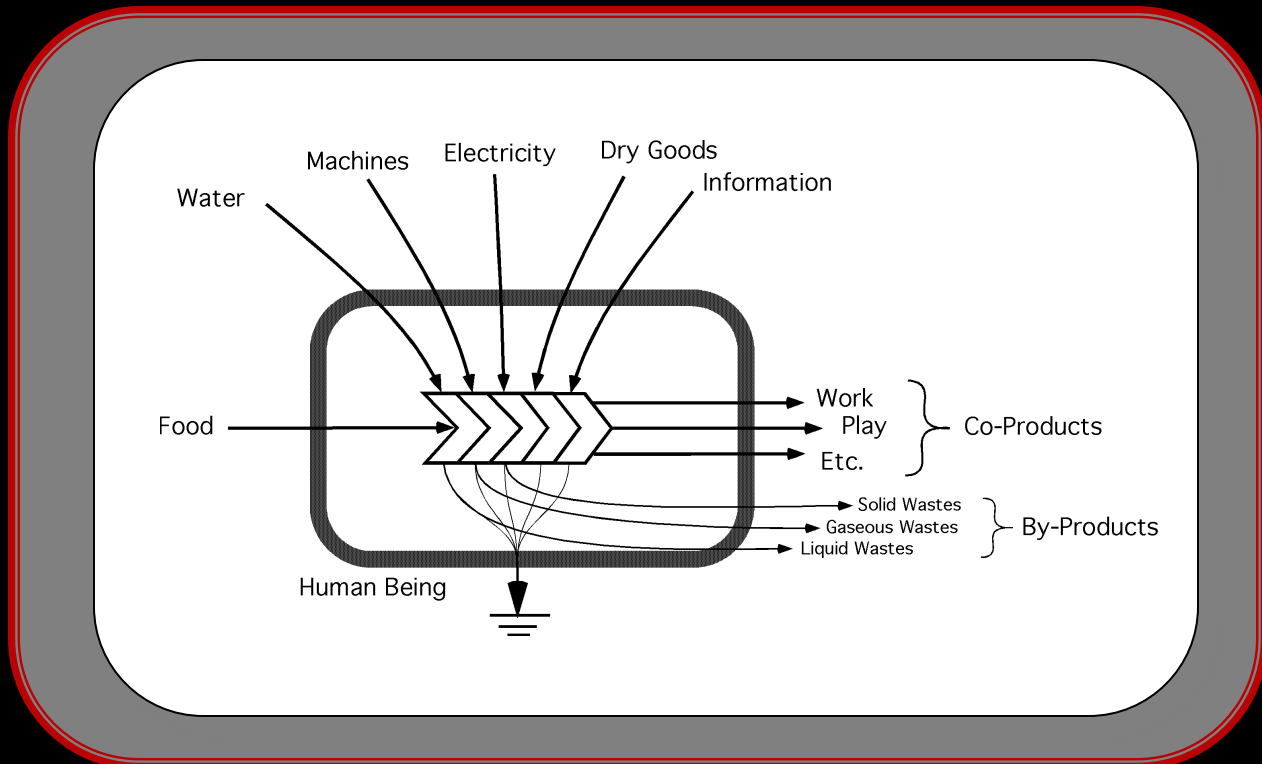
Clearly the outputs from the human individual are co-products



Theoretical Consideration…

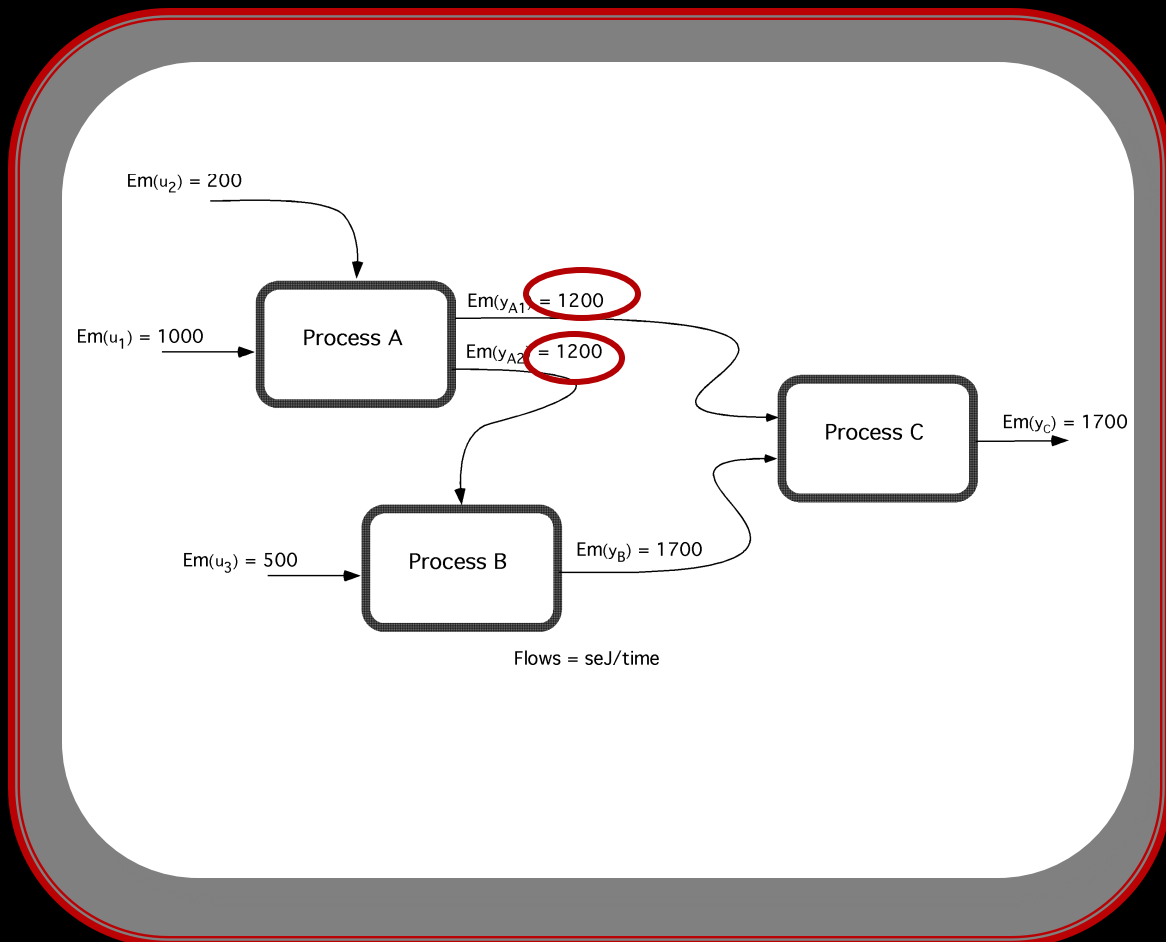
Human co-products and by-products

…but what about by-products?



Theoretical Consideration…

What if there is a delay in the system such that the bottom co-product inflow to Process B is not produced with the same emergy as the top co-product?

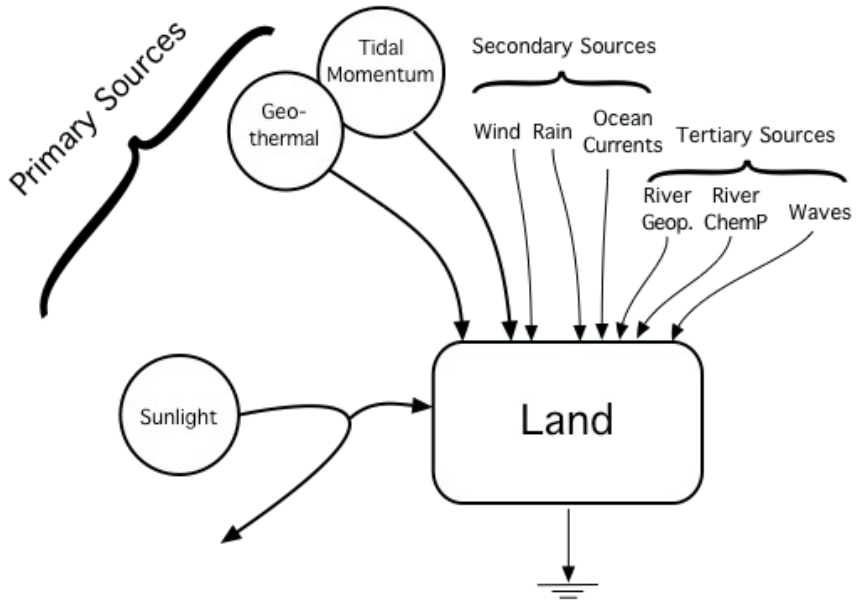


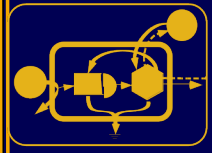
Emergy Algebra...

IMPORTANT Consideration…

Input Emergy =

Maximum of Sum of the Primary vs. largest of the secondary & tertiary sources





Questions ?

Comments ?

Concerns?