OSU~EmEA-15

Emergy &
The Circular Economy

Circular Economy …

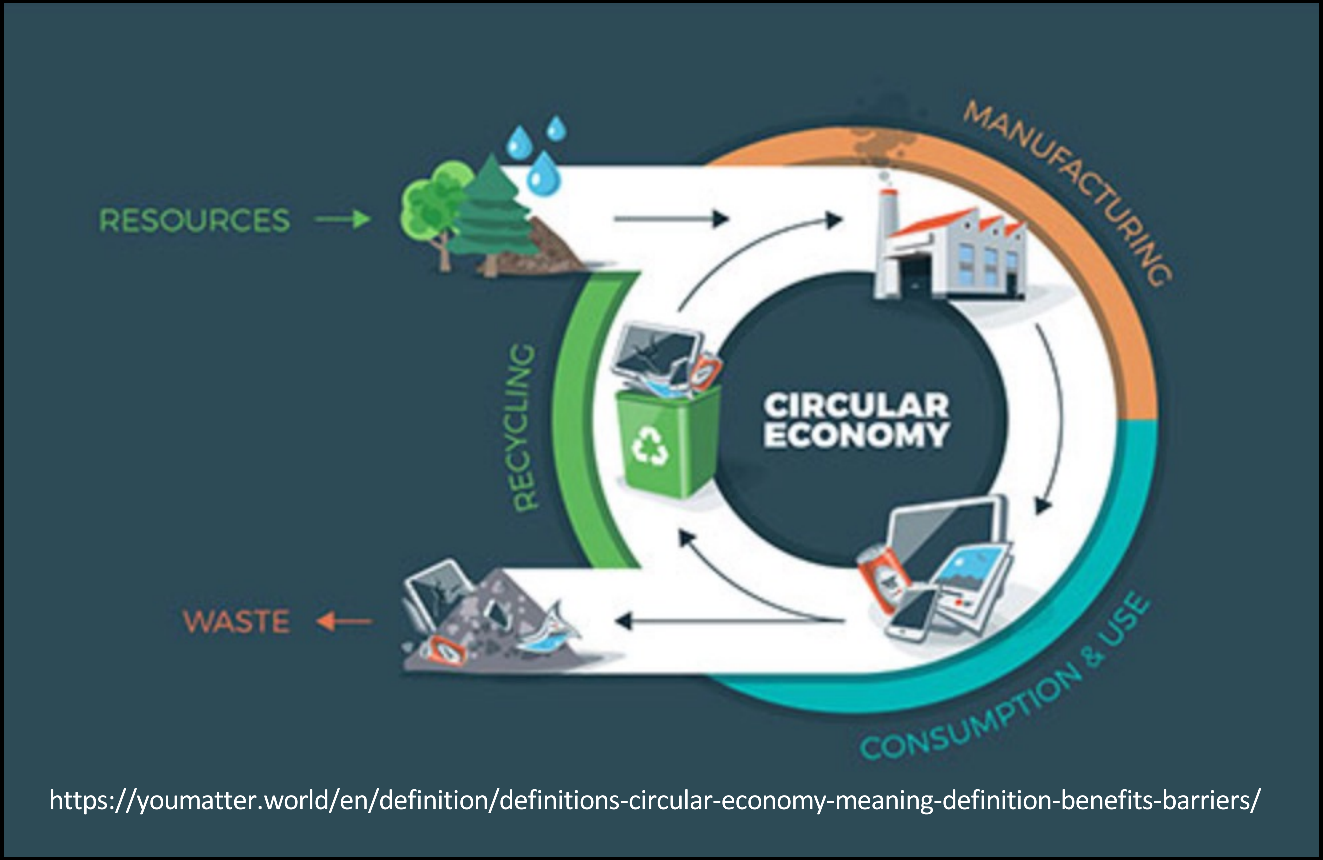
“Circular Economy” defined
Dimensions of circular economy
Materials recycle
InFORMation
Recycle of products, co-products and by-products

Circular Economy …

Google “Circular Economy” and you’ll get 182,000,000 hits

Circular Economy is BIG !

(Google “Emergy” and you’ll get ~ 600,000 hits)

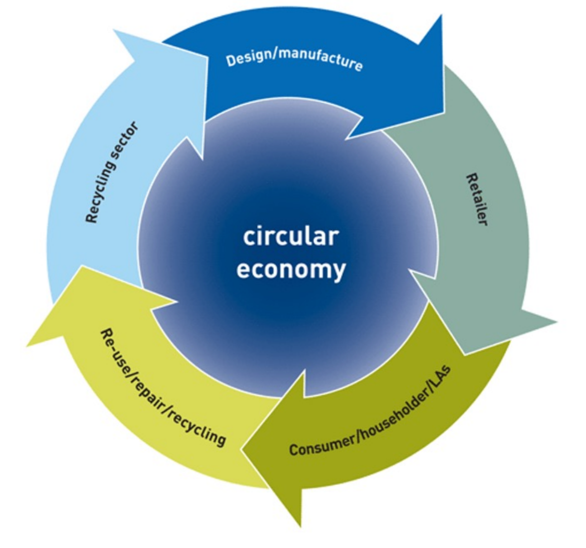


https://youmatter.world/en/definition/definitions-circular-economy-meaning-definition-benefits-barriers/

Circular Economy …

A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems, and business models.

World Economic Forum



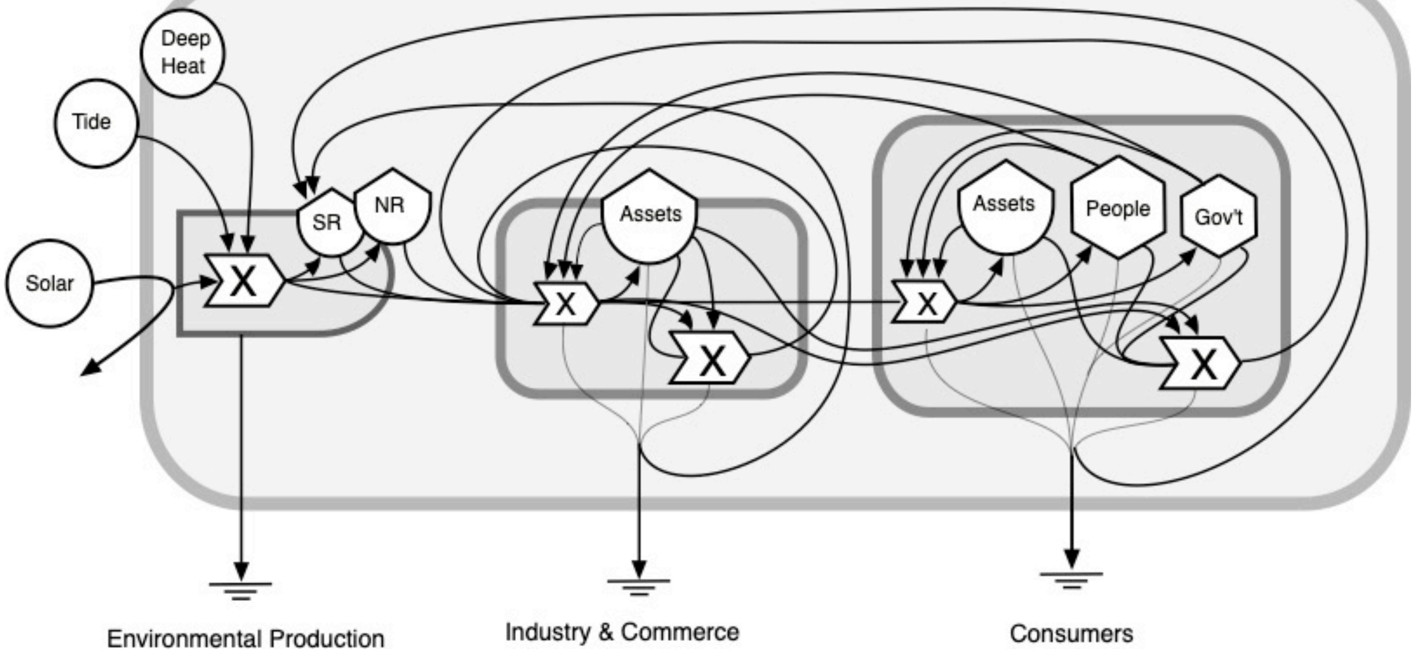
Circular Economy …

The circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. In this way, the life cycle of products is extended.

European Parliament

https://www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy-definition-importance-and-benefits

Circular Economy …



circular Economy ...

The flux of emergy and mass in the global economy 2014.

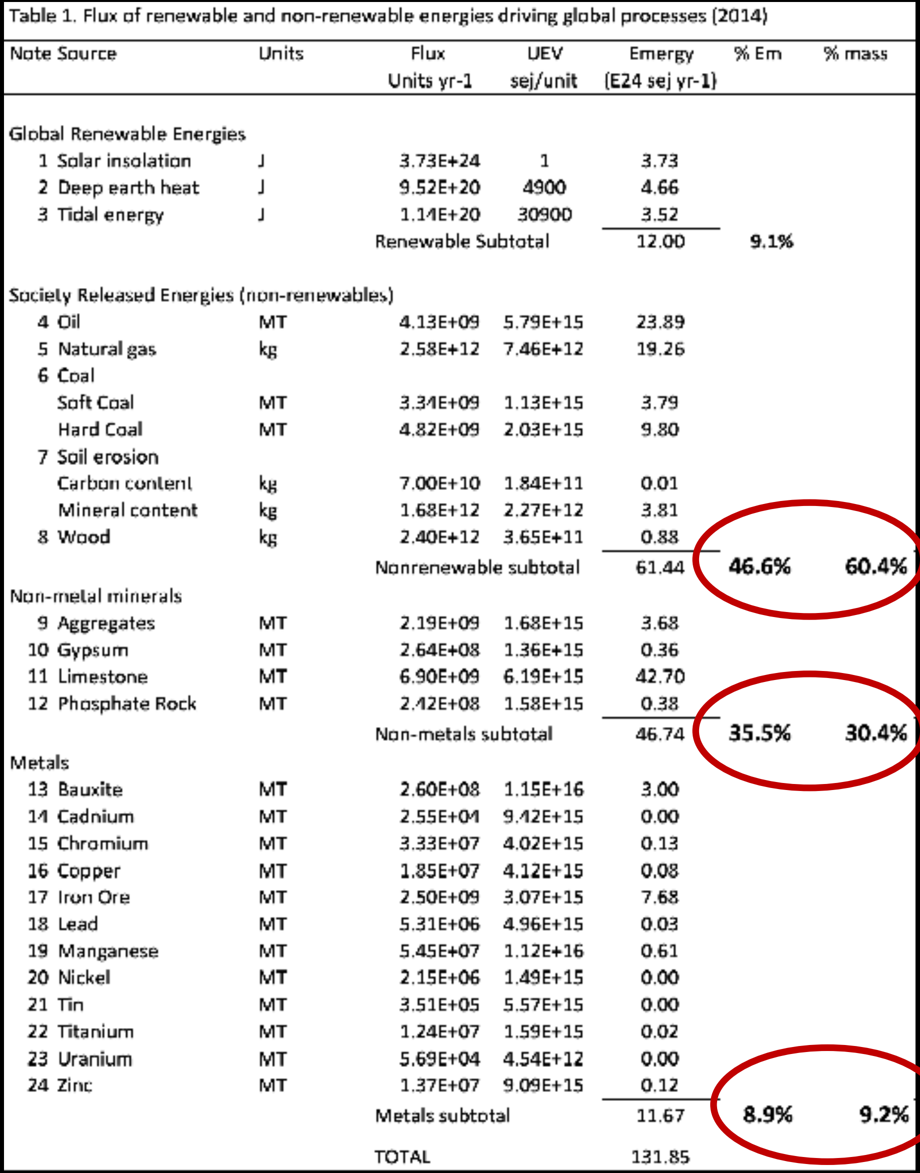
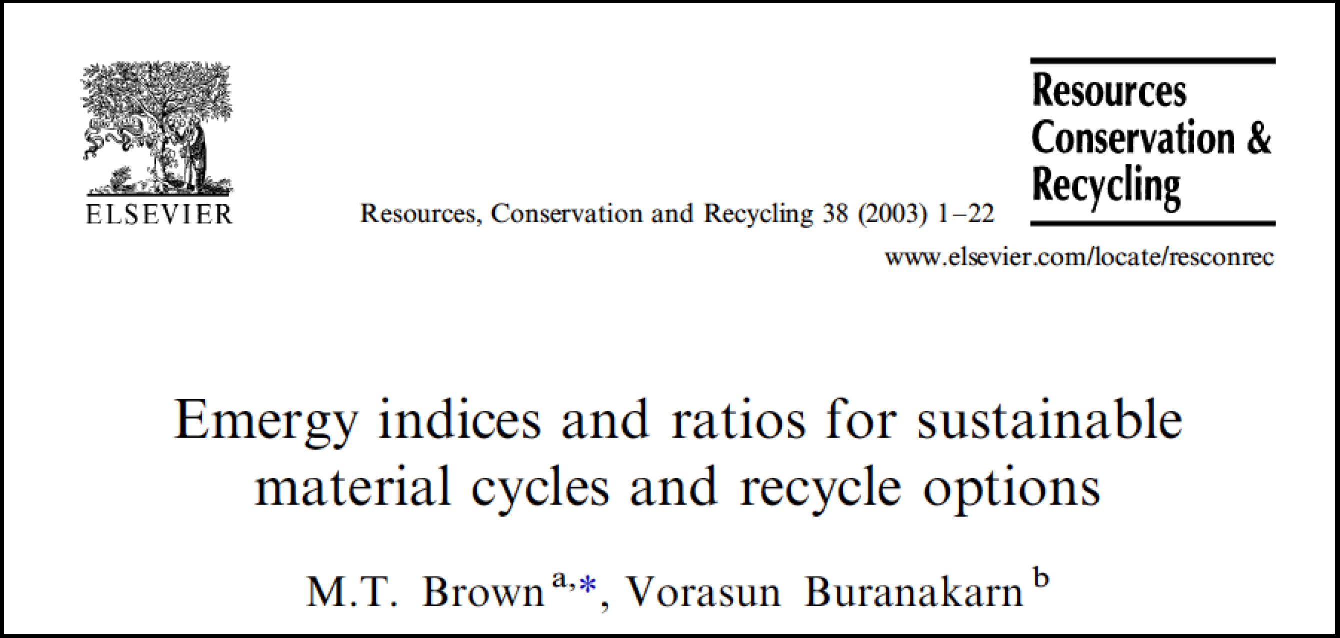


Table 1. Flux of renewable and non-renewable energies driving global processes (2014)

Note	Source	Units	Flux Units yr-1	UEV sej/unit	Emergy (E24 sej yr-1)	% Em	% mass
	Global Renewable Energies						
1	Solar insolation	J	3.73E+24	1	3.73		
2	Deep earth heat	J	9.52E+20	4900	4.66		
3	Tidal energy	J	1.14E+20	30900	3.52		
			Renewable Subtotal		12.00	9.1%	
	Society Released Energies (non-renewables)						
4	Oil	MT	4.13E+09	5.79E+15	23.89		
5	Natural gas	kg	2.58E+12	7.46E+12	19.26		
6	Coal						
	Soft Coal	MT	3.34E+09	1.13E+15	3.79		
	Hard Coal	MT	4.82E+09	2.03E+15	9.80		
7	Soil erosion						
	Carbon content	kg	7.00E+10	1.84E+11	0.01		
	Mineral content	kg	1.68E+12	2.27E+12	3.81		
8	Wood	kg	2.40E+12	3.65E+11	0.88		
			Nonrenewable subtotal		61.44	46.6%	60.4%
	Non-metal minerals						
9	Aggregates	MT	2.19E+09	1.68E+15	3.68		
10	Gypsum	MT	2.64E+08	1.36E+15	0.36		
11	Limestone	MT	6.90E+09	6.19E+15	42.70		
12	Phosphate Rock	MT	2.42E+08	1.58E+15	0.38		
			Non-metals subtotal		46.74	35.5%	30.4%
	Metals						
13	Bauxite	MT	2.60E+08	1.15E+16	3.00		
14	Cadnium	MT	2.55E+04	9.42E+15	0.00		
15	Chromium	MT	3.33E+07	4.02E+15	0.13		
16	Copper	MT	1.85E+07	4.12E+15	0.08		
17	Iron Ore	MT	2.50E+09	3.07E+15	7.68		
18	Lead	MT	5.31E+06	4.96E+15	0.03		
19	Manganese	MT	5.45E+07	1.12E+16	0.61		
20	Nickel	MT	2.15E+06	1.49E+15	0.00		
21	Tin	MT	3.51E+05	5.57E+15	0.00		
22	Titanium	MT	1.24E+07	1.59E+15	0.02		
23	Uranium	MT	5.69E+04	4.54E+12	0.00		
24	Zinc	MT	1.37E+07	9.09E+15	0.12		
			Metals subtotal		11.67	8.9%	9.2%
			TOTAL		131.85		

Material Cycles …



ELSEVIER

Resources, Conservation and Recycling 38 (2003) 1–22

Resources
Conservation &
Recycling

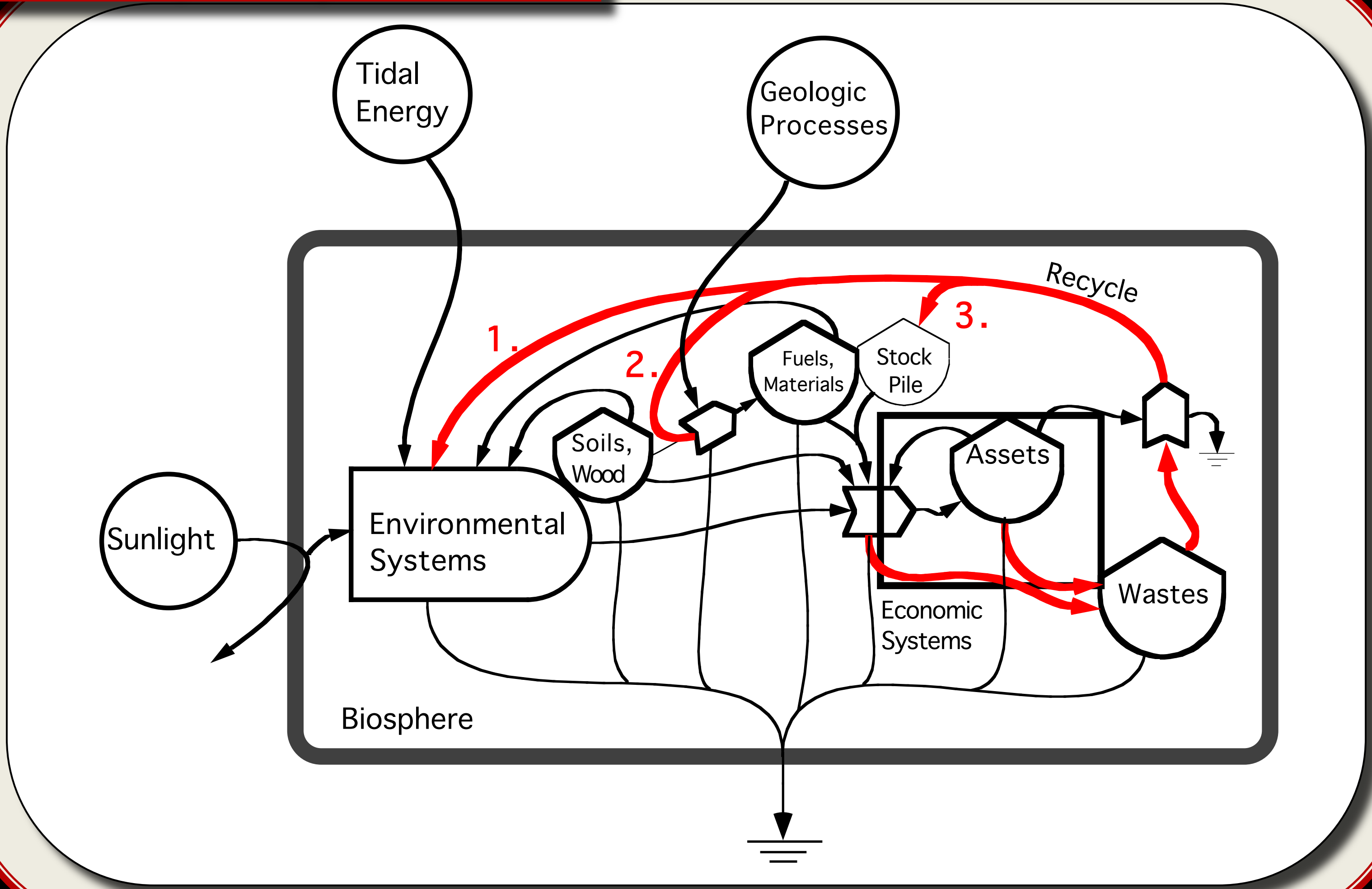
www.elsevier.com/locate/resconrec

Emergy indices and ratios for sustainable material cycles and recycle options

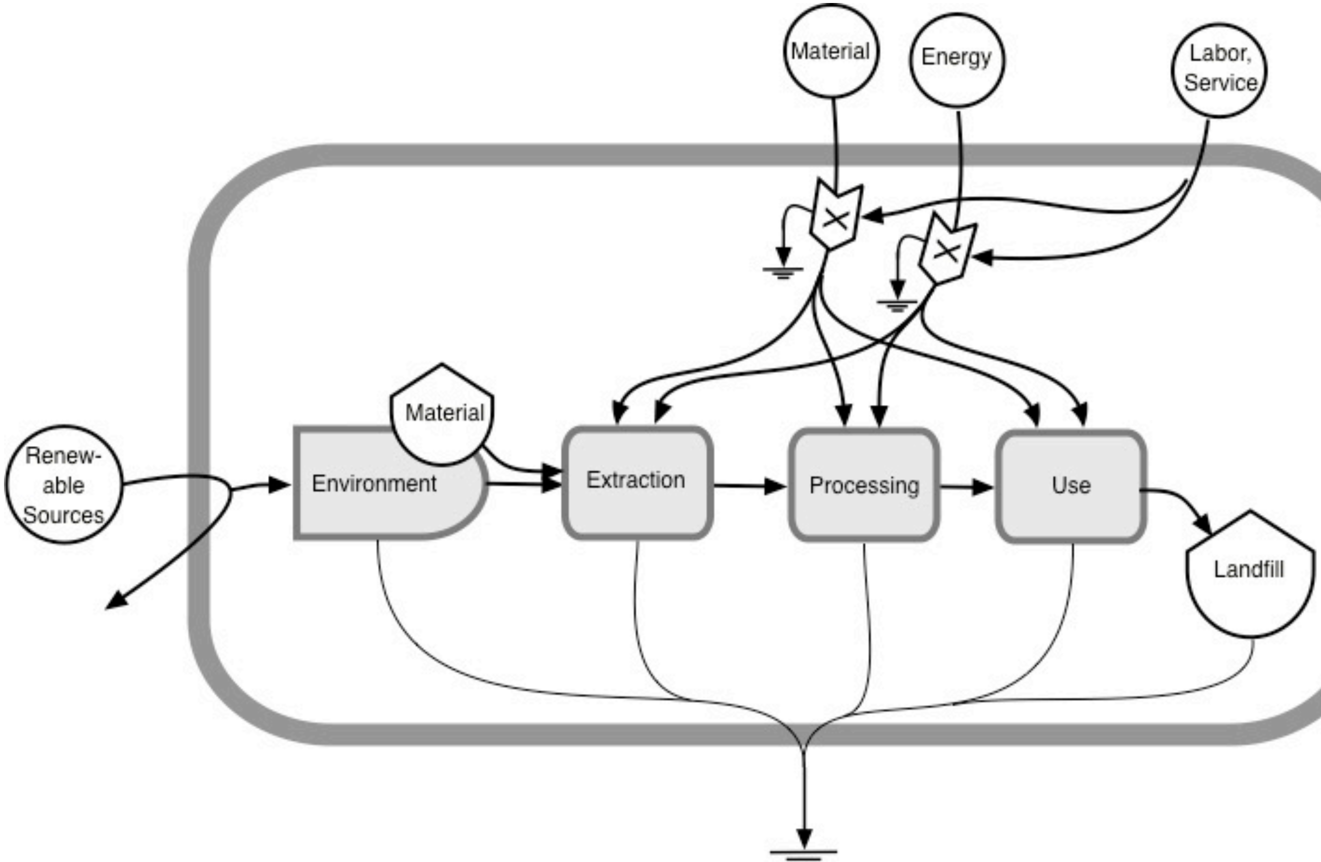
M.T. Brown[a,*], Vorasun Buranakarn[b]

Material Cycles ...

Recycle of waste products follows one of three pathways...

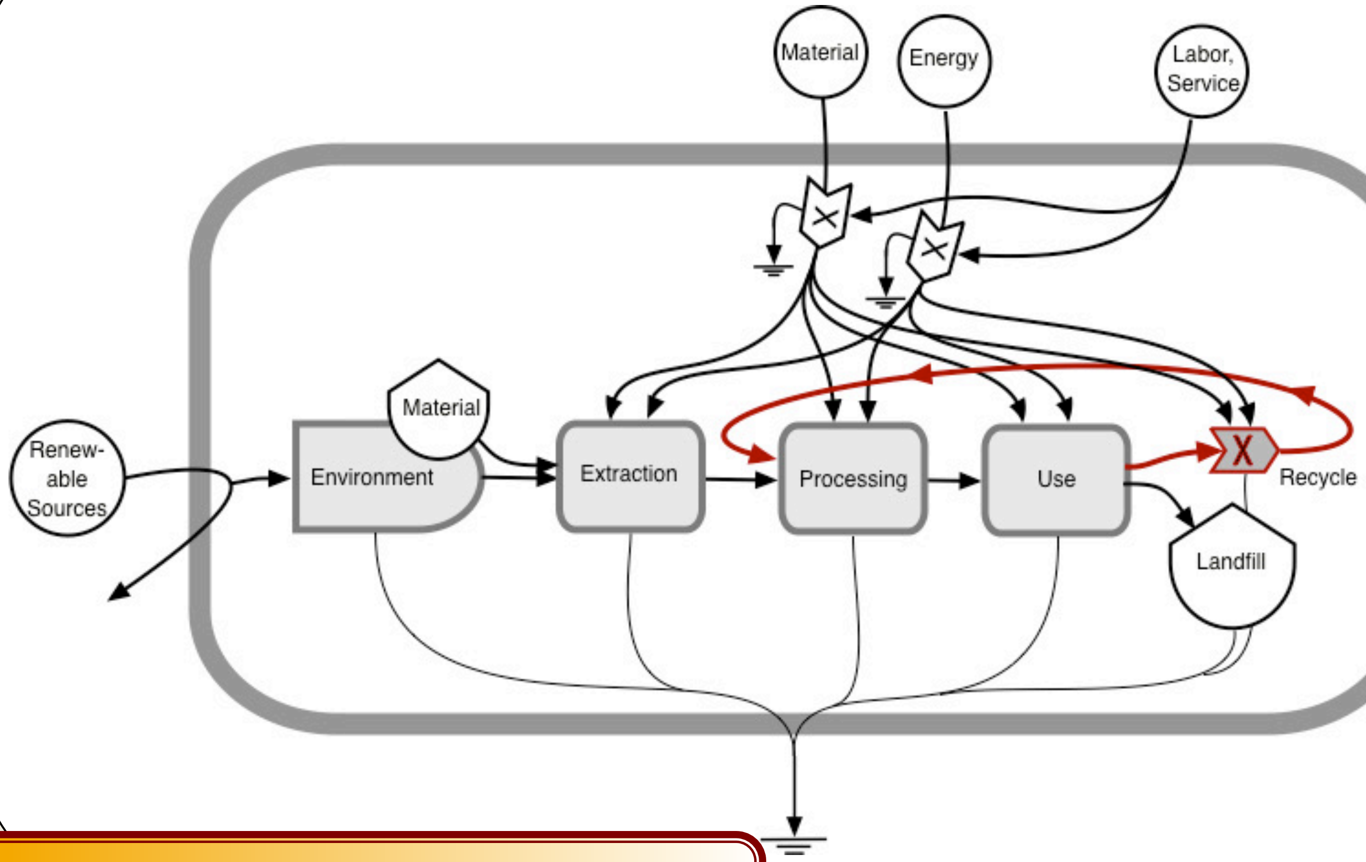


Material cycles ...



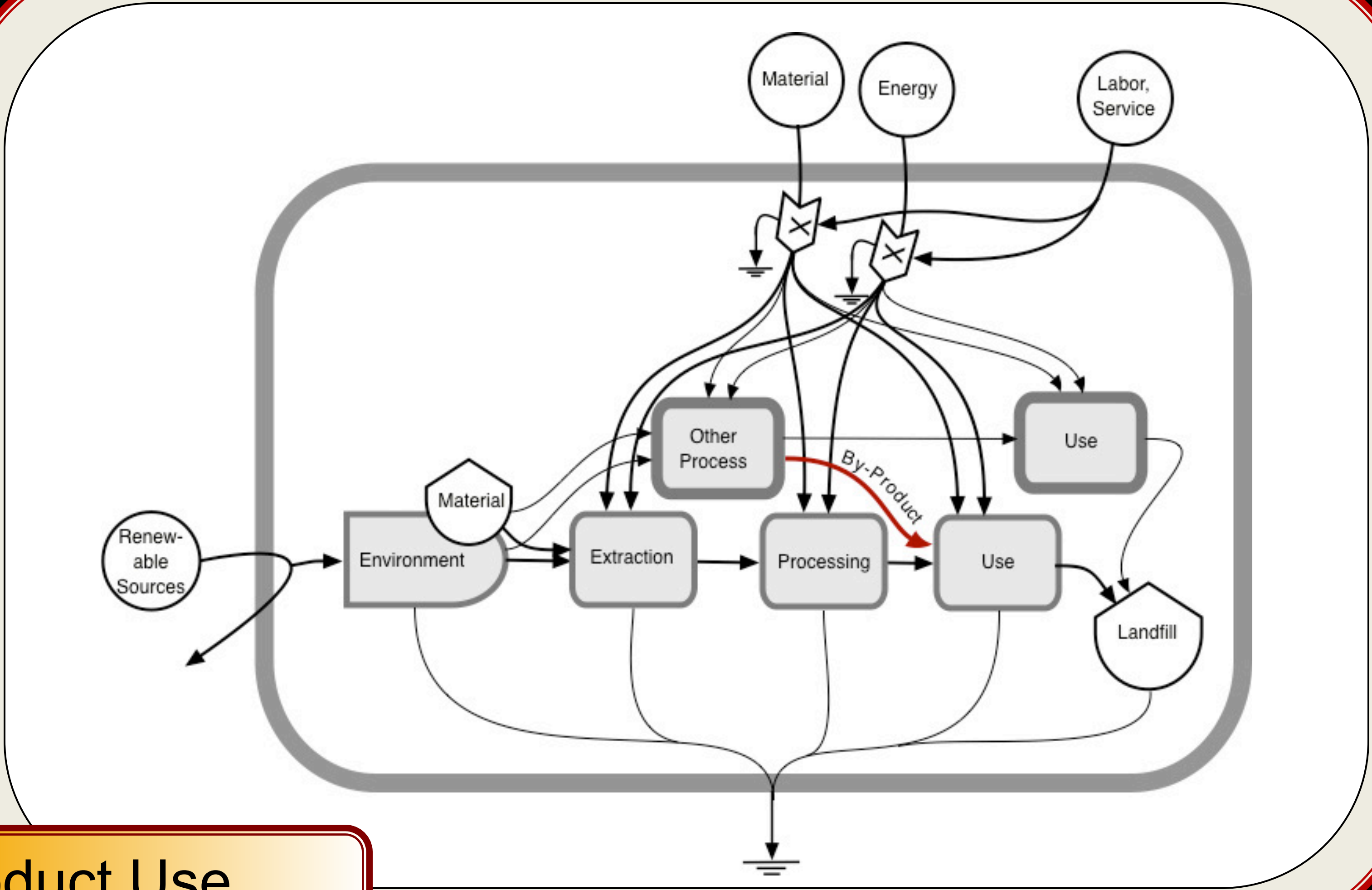
Standard material cycle...

Material cycles ...



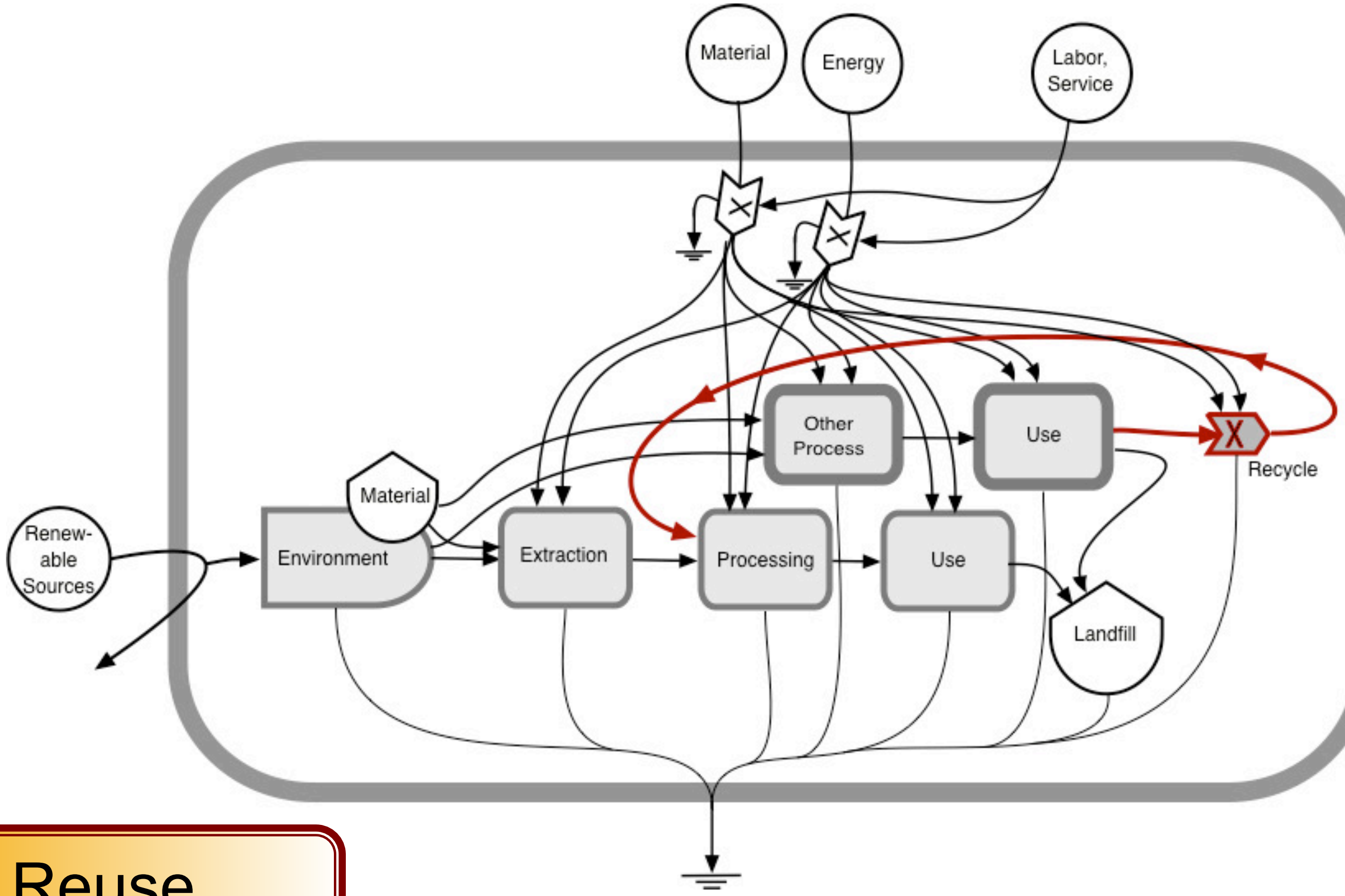
Standard cycle with RECYCLE...

Material cycles ...



By-Product Use...

Material cycles ...



Adaptive Reuse...

Recycle Ratios …

Performance and Efficiency Ratios

- Recycle Benefit Ratio (RBR)
- Recycle Yield Ratio (RYR)
- Landfill to Recycle Ratio (LRR)
- Recycle Efficiency Ratio (RER)

Recycle Ratios …

Recycle Benefit Ratio

$= A_1/C_2$

Recycle Yield Ratio

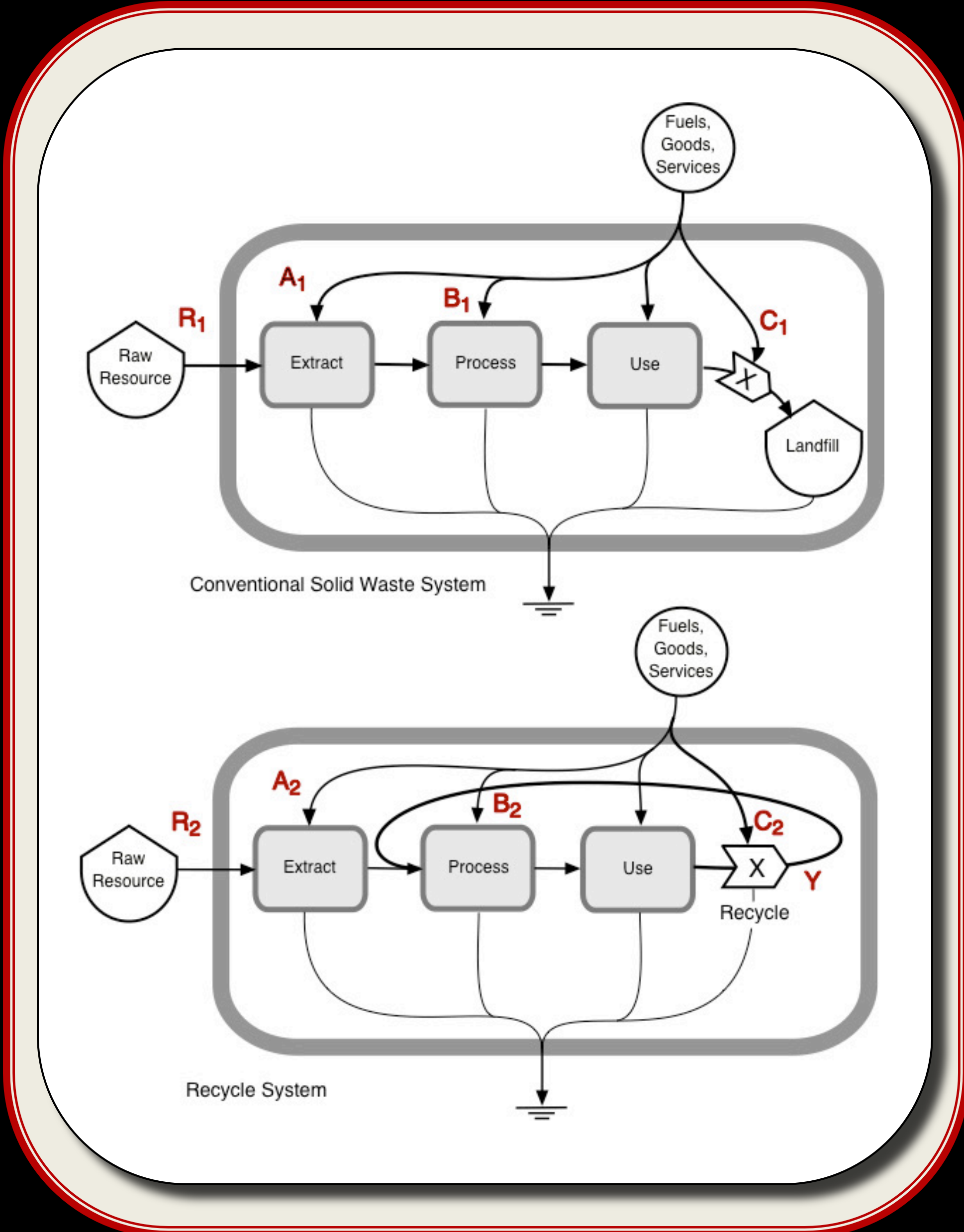
$= Y/C_2$

Landfill to Recycle Ratio

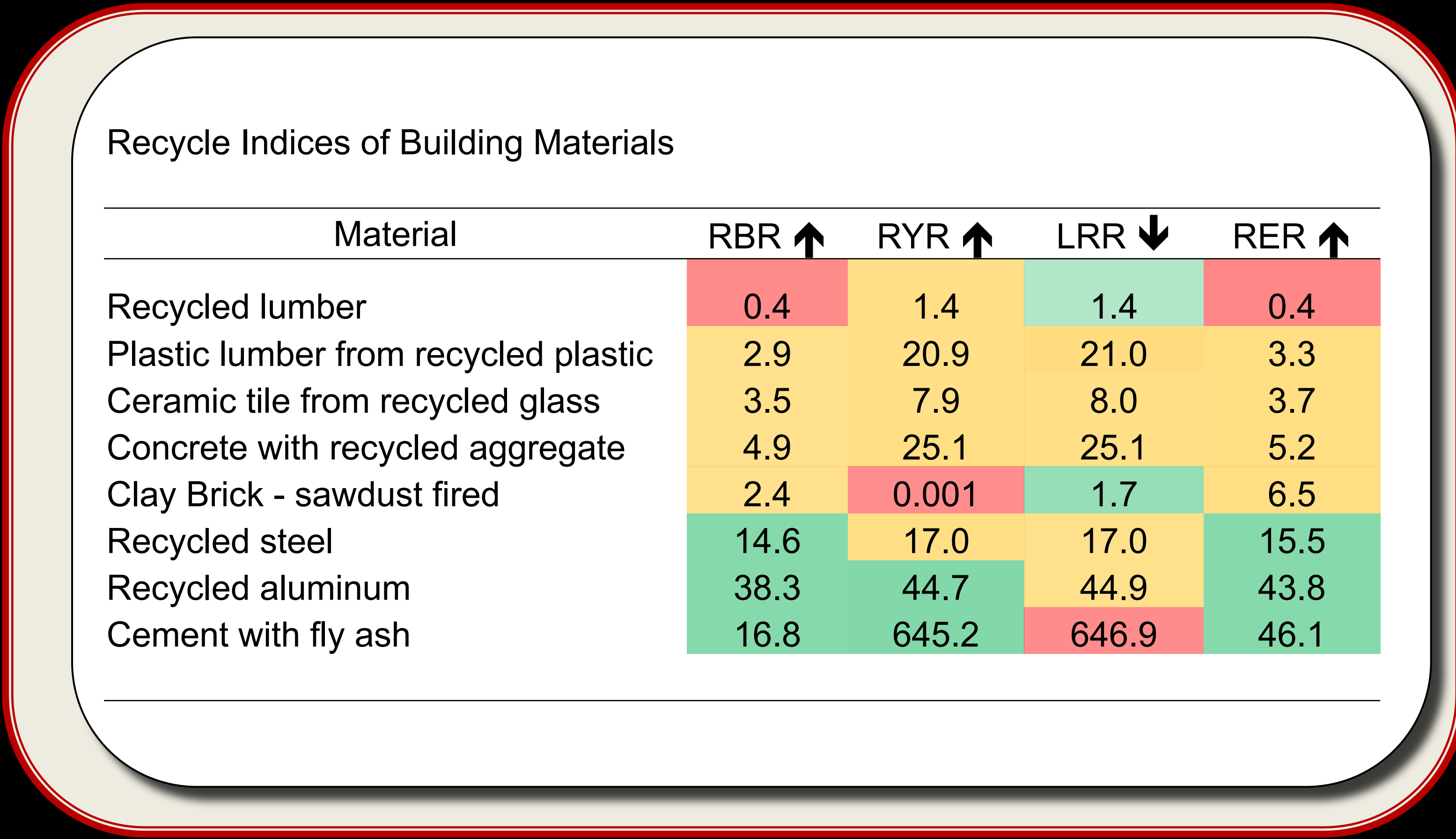
$= C_1/C_2$

Recycle Efficiency Ratio

$$= [(R_1+A_1+B_1+C_1) - (R_2+A_2+B_2+C_2)] / C_2$$



Recycle Indices …



Recycle Indices of Building Materials

Material	RBR ↑	RYR ↑	LRR ↓	RER ↑
Recycled lumber	0.4	1.4	1.4	0.4
Plastic lumber from recycled plastic	2.9	20.9	21.0	3.3
Ceramic tile from recycled glass	3.5	7.9	8.0	3.7
Concrete with recycled aggregate	4.9	25.1	25.1	5.2
Clay Brick - sawdust fired	2.4	0.001	1.7	6.5
Recycled steel	14.6	17.0	17.0	15.5
Recycled aluminum	38.3	44.7	44.9	43.8
Cement with fly ash	16.8	645.2	646.9	46.1

RBR = Recycle Benefit Ratio
RYR = Recycle Yield Ratio
LRR = Landfill to Recycle Ratio
RER = Recycle Efficiency Ratio

Materials and material quality

1.Emergy per mass may be a good indicator of recycle-ability.

2.The emprice (emergy received for money spent) is highest for primary building materials and lowest for materials that contain more human services.

3.Quality and versatility of a material are related to emergy per mass. The larger the emergy per mass, the more valuable and versatile the product and the greater the potential for recycle.

4.The emergy yield ratio (EYR) may provide important information regarding recycle-ability.

5.Price, expressed as mass per dollar is inverse to the amount of human service inputs to a material’s production.

Recycling Patterns

1. Materials that have large refining costs have greatest potential for high recycle benefits.

2. The highest benefits to society appear to accrue from material recycle systems, followed by adaptive reuse systems, and finally by by-product reuse systems.

3.The landfill recycle ratios for all the material recycle systems studied, with the exception of glass, were less than one. This may result from the fact that environmental impacts of landfilling were not evaluated.

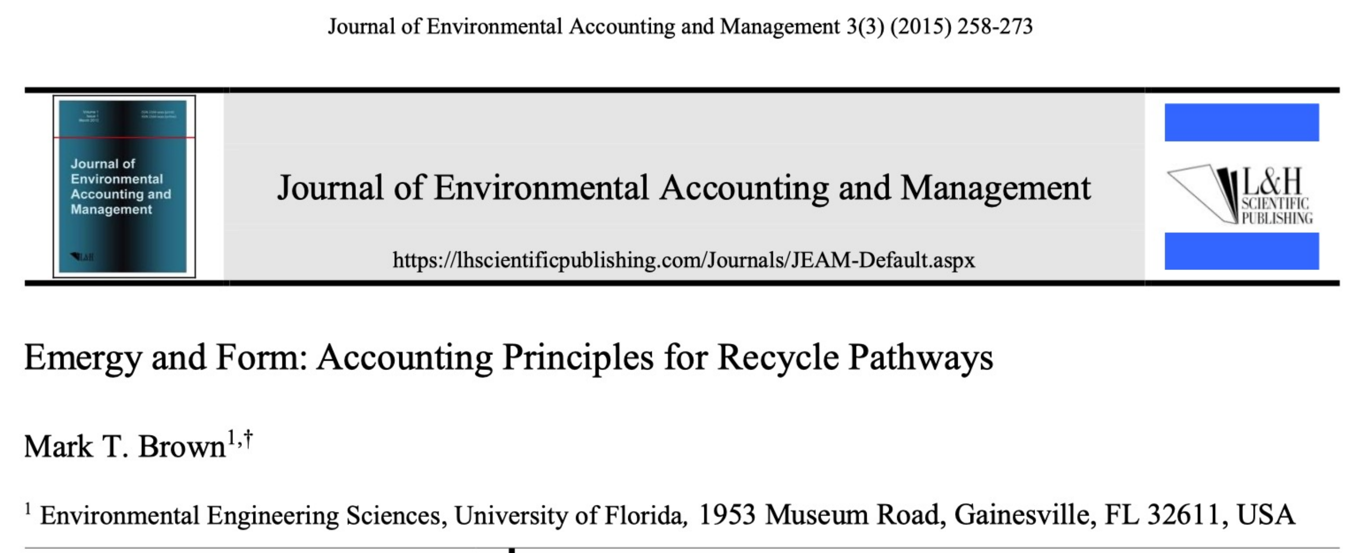
4.The yields from recycling are extremely high, far greater than the yields that society obtains from energy sources indicating the very important contributions that effective recycling systems will have in the long run.

Emformation …

Information….

inFORMation..

EMformation…



Journal of Environmental Accounting and Management 3(3) (2015) 258-273

Journal of Environmental Accounting and Management

https://lhscientificpublishing.com/Journals/JEAM-Default.aspx

Emergy and Form: Accounting Principles for Recycle Pathways

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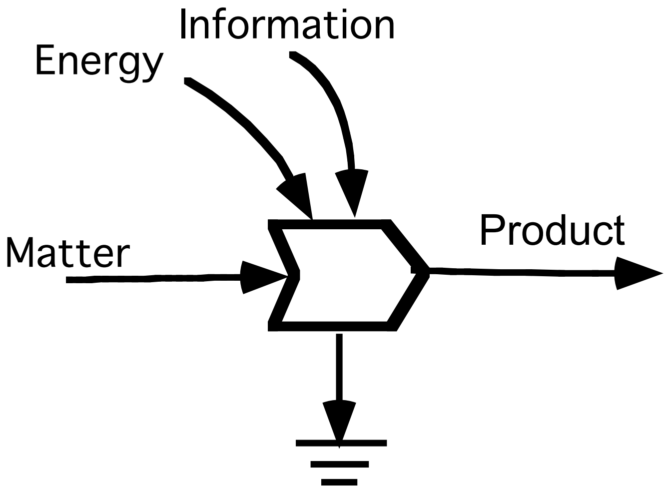
Emformation …

All processes require three driving energies…

The emergy of a product comes from three sources, the material it is made from, the energy required to form it, and the information that is in it’s form

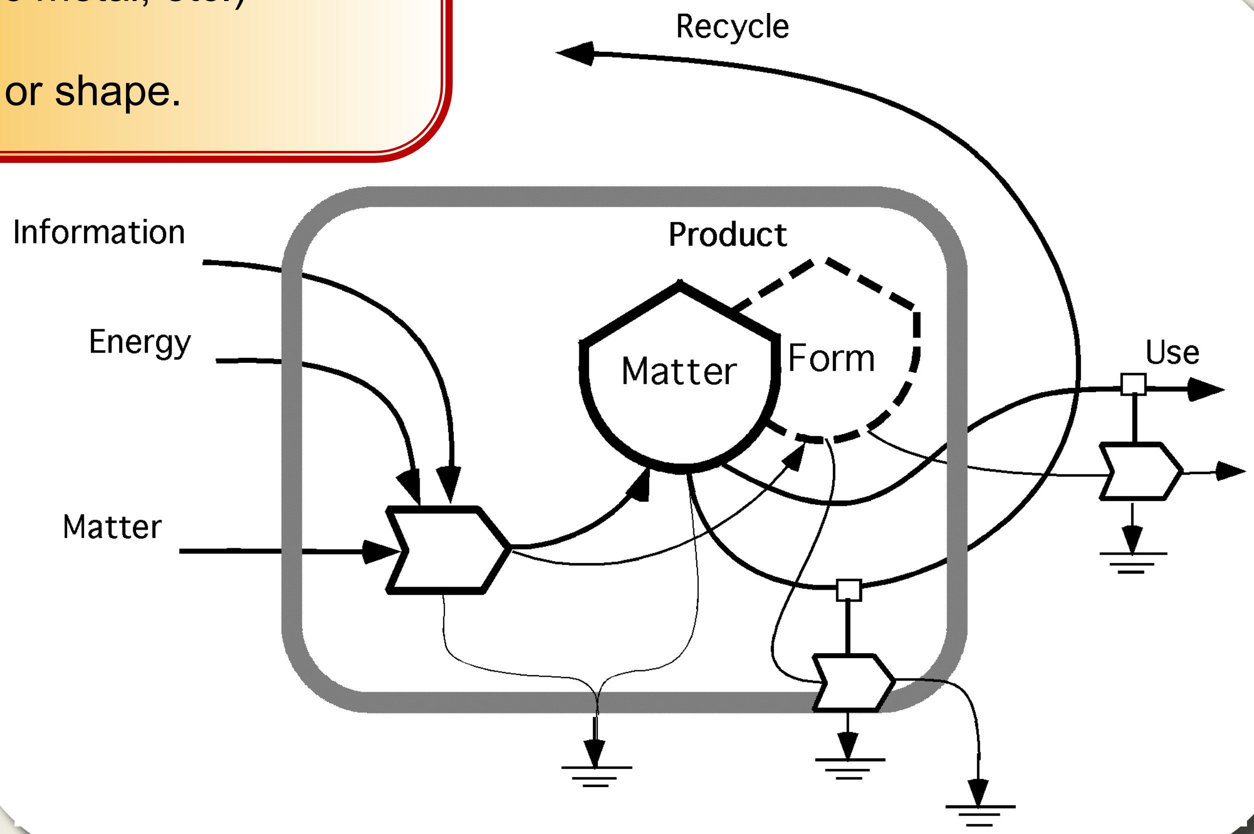


Information ...

All products have two states that determine their use and functionality.

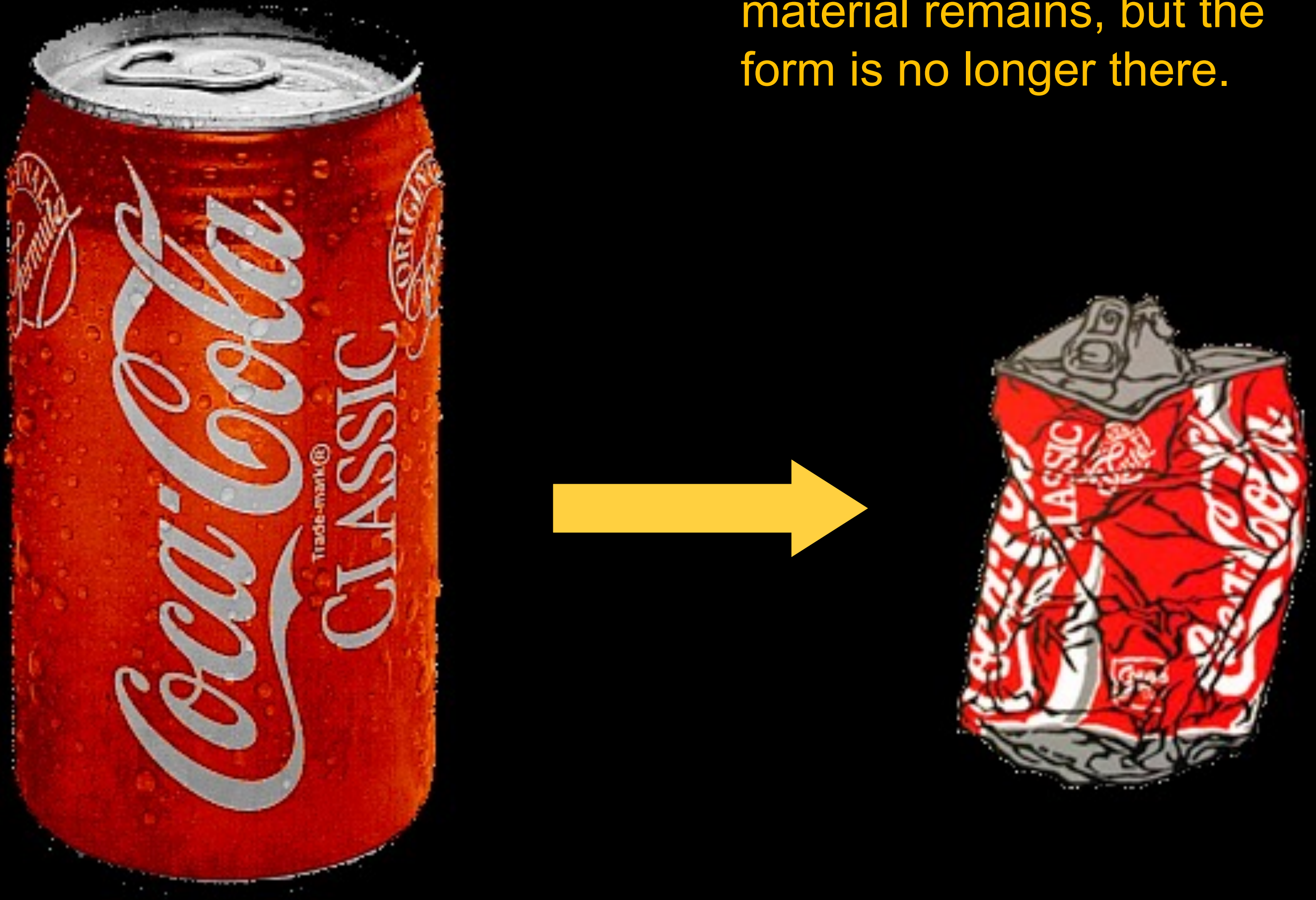
The first is the material from which it is made (i.e. wood, plastic metal, etc.)

The second is its form or shape.



Form as Information …

When the can is crushed, the material remains, but the form is no longer there.



Emergy in Material and Form…

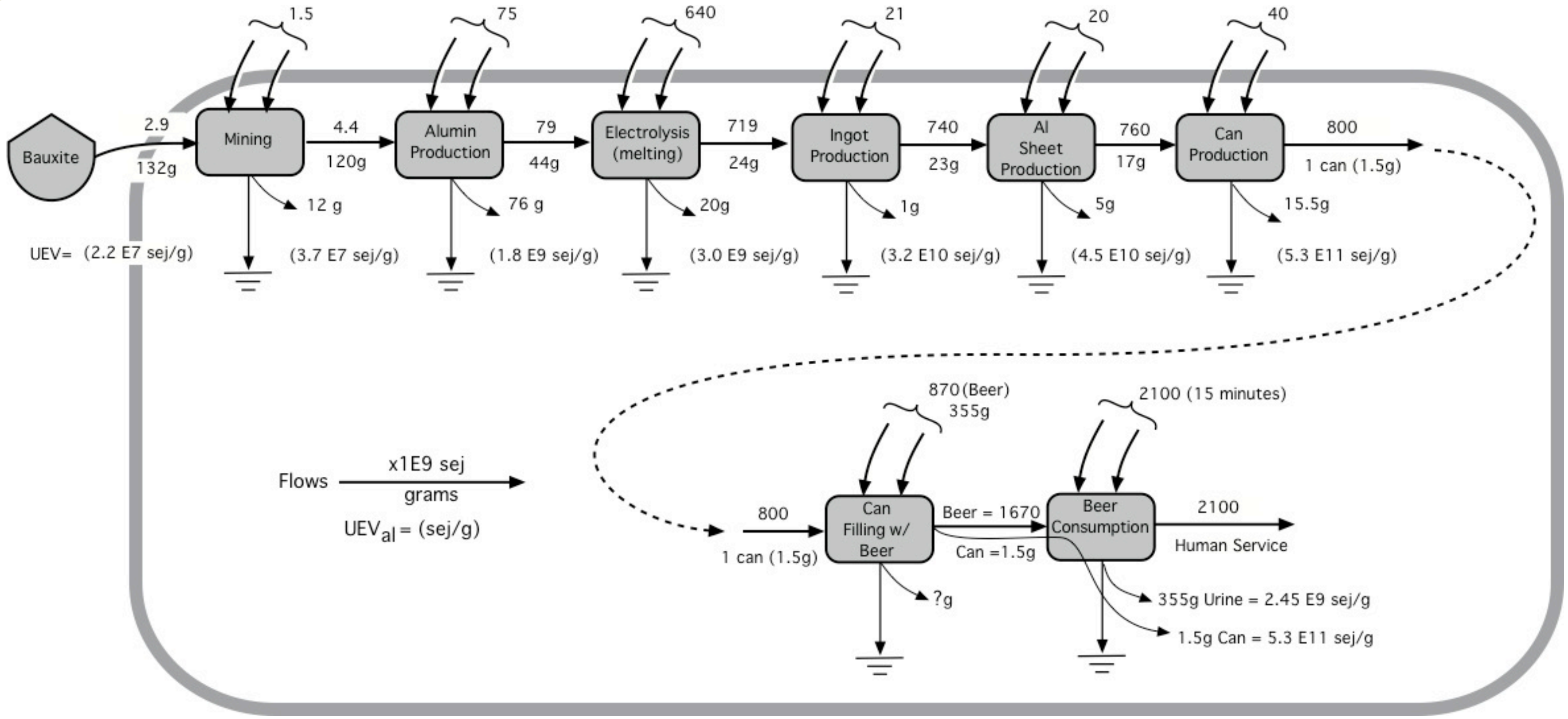
Table 3. Material emergy and Emformation* of common building materials

Material	Raw Material (E9 sej/g)	Finished Product (E9 sej/g)	Emformation* (E9 sej/g)
Wood Lumber	0.59	2.43	1.84 (76%)
Glass	1.35	8.66	7.31 (84%)
Aluminum	2.16	12.68	10.52 (83%)
Steel	2.44	3.85	1.41 (37%)

*Emformation is equal to the difference between emergy of the finished product and the raw material emergy.

Information ...

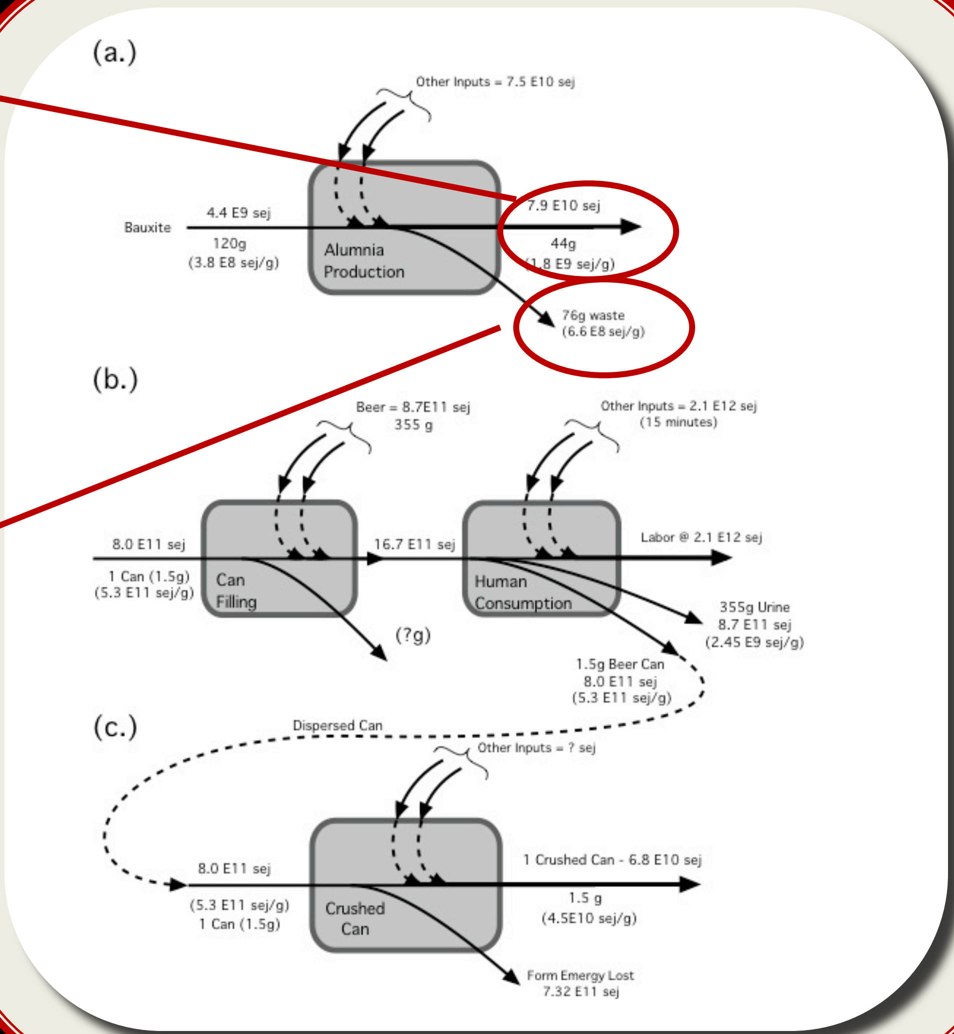
Emergy of a beer can life cycle



Emformation ...

The emergy of the product is equal to the sum of the inputs (7.9 E10 sej) and UEV = 1.8 E9 sej/g

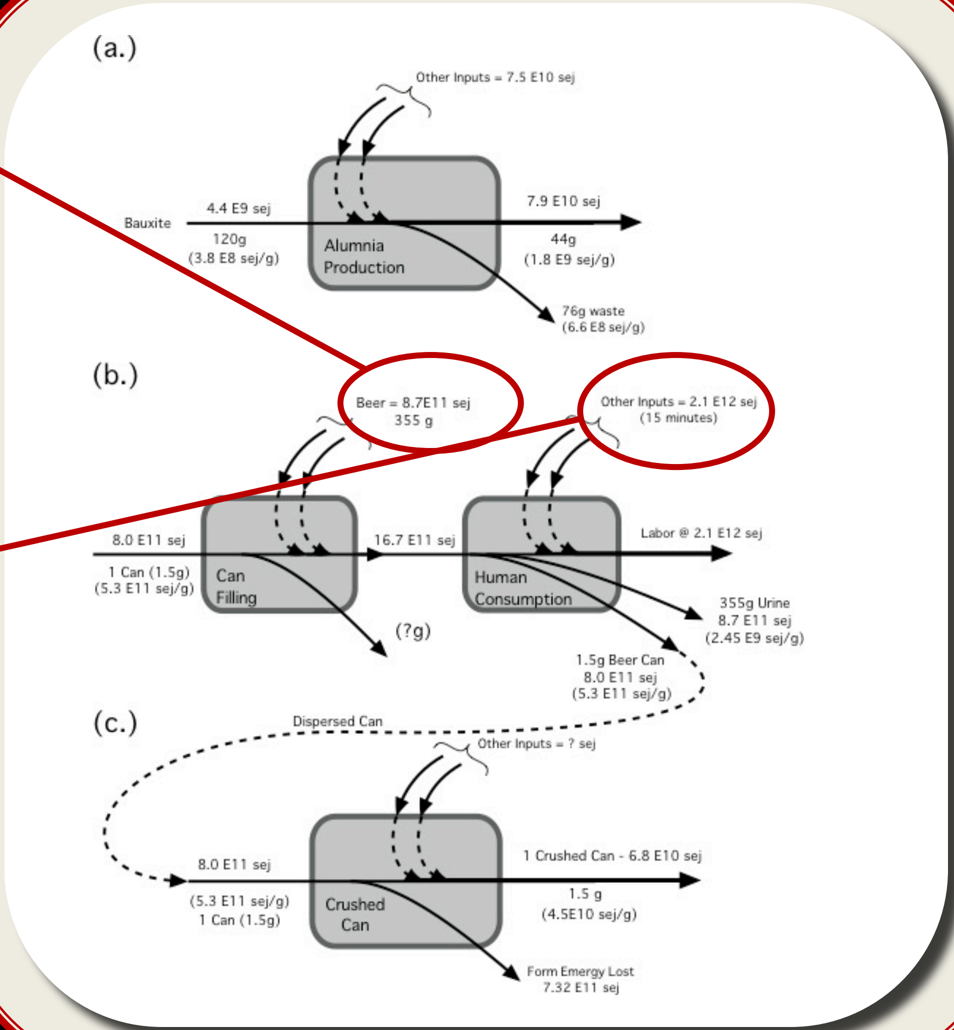
The UEV of the waste flow equals the sum of the inputs divided by the total quantity of material produced (product + waste), (6.6 E8 sej/g) and the emergy equals 76 * 6.6 E8 = 5.0 E10 sej



Emformation …

It is interesting to note that the emergy of the can is almost equal to the emergy of the beer

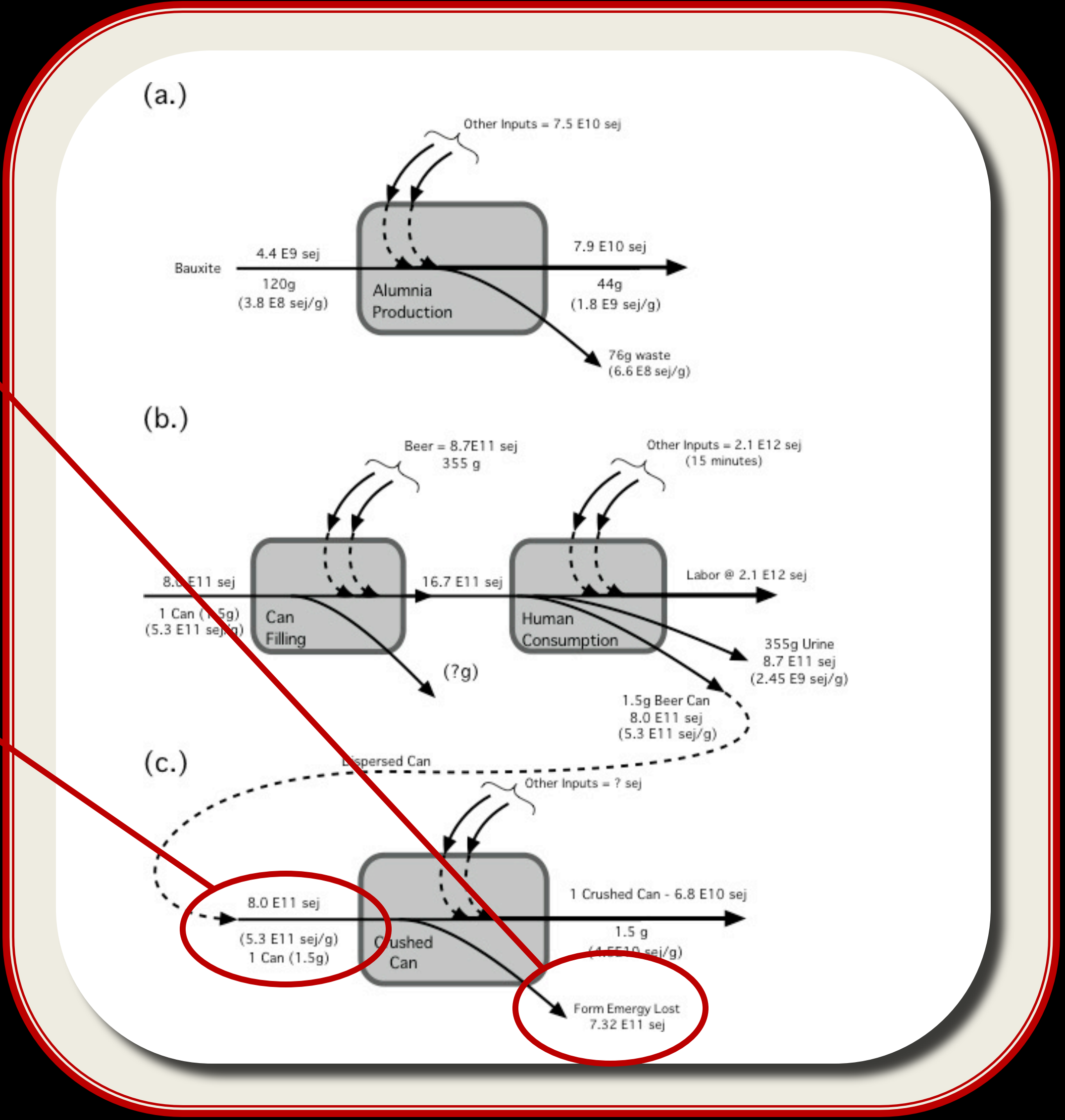
Also of interest is the emergy of the human while drinking for 15 minutes is about 1.25x that of the beer and can.



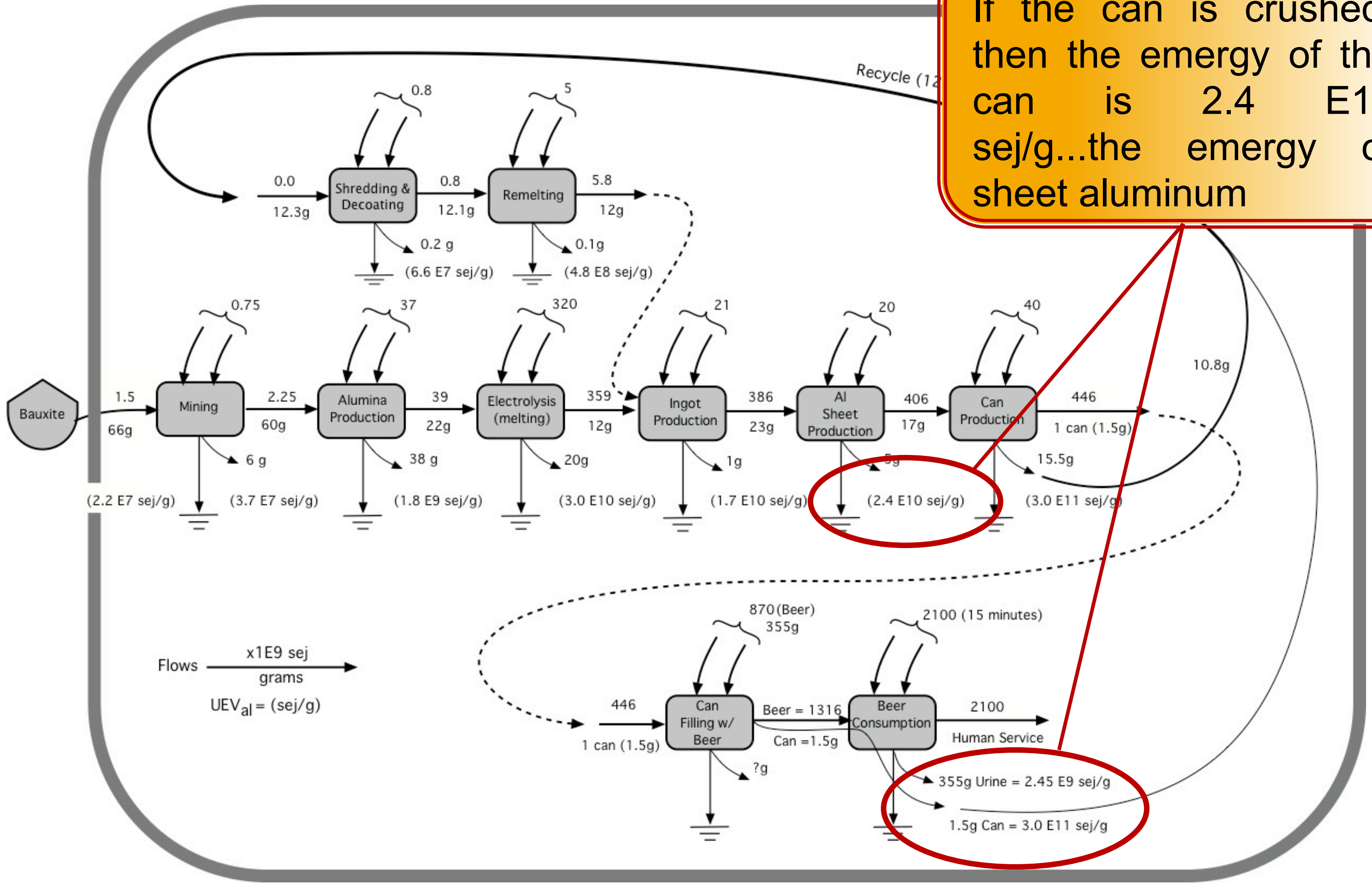
Information ...

If the can is crushed, the emergy of the form is lost, and the emergy remaining in the can is the emergy of sheet aluminum.

The empty can still has the emergy of the can before drinking, however the emergy of the beer is not in the can.

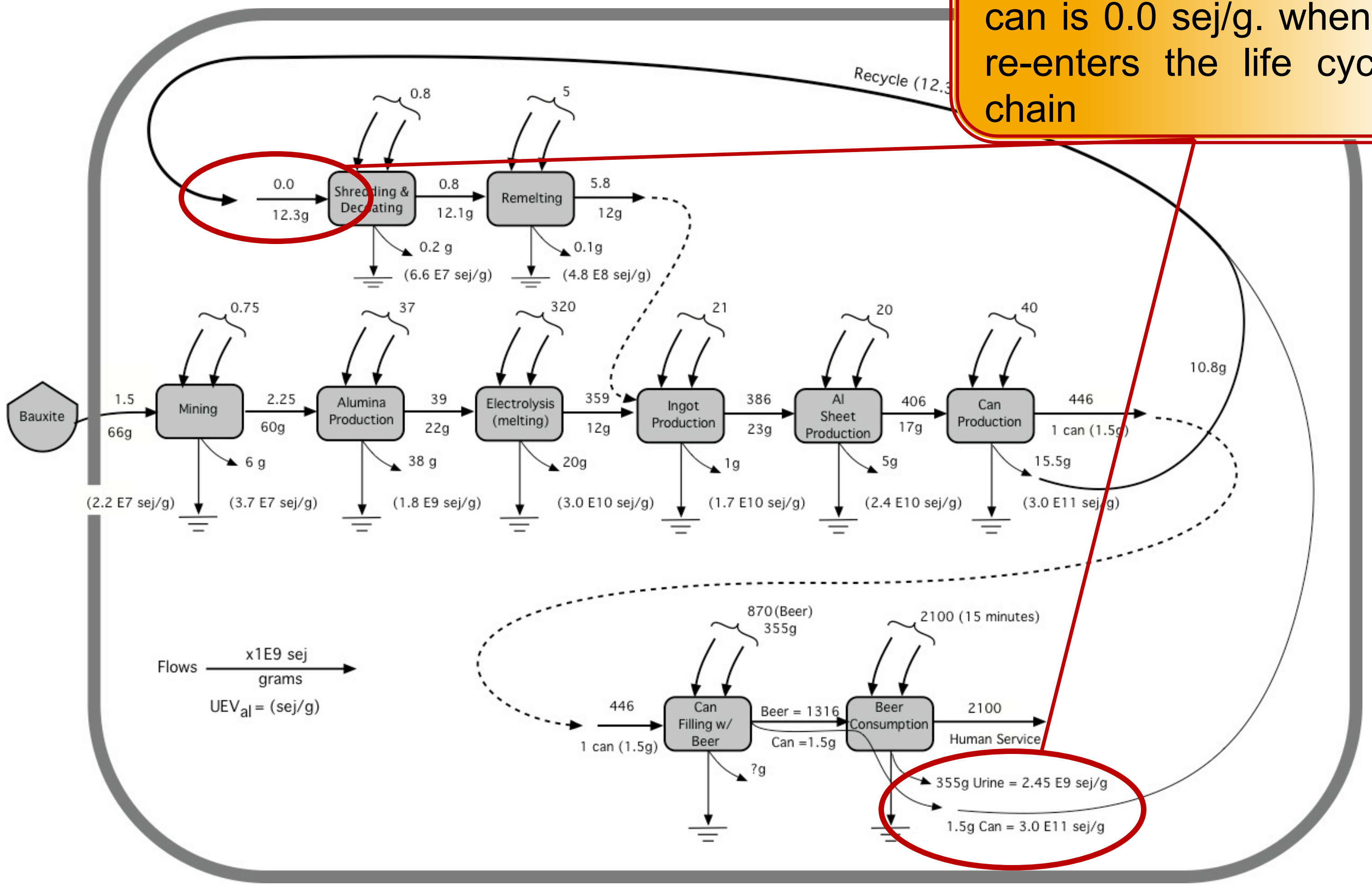


Emformation ...



If the can is crushed, then the emergy of the can is 2.4 E10 sej/g...the emergy of sheet aluminum

Emformation ...

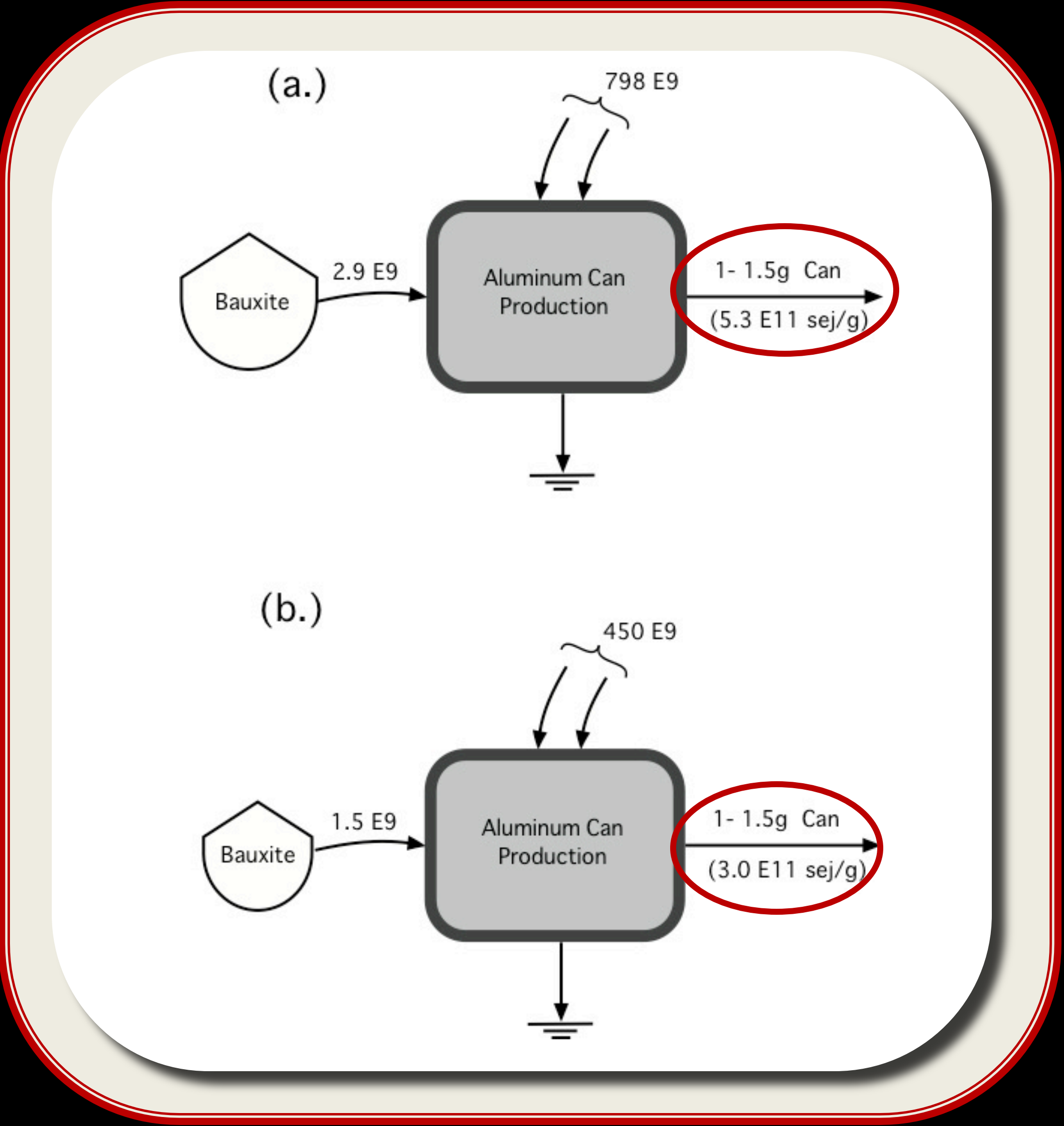


If the can is recycled, then the emergy of the can is 0.0 sej/g. when it re-enters the life cycle chain

Emformation …

Without can recycle

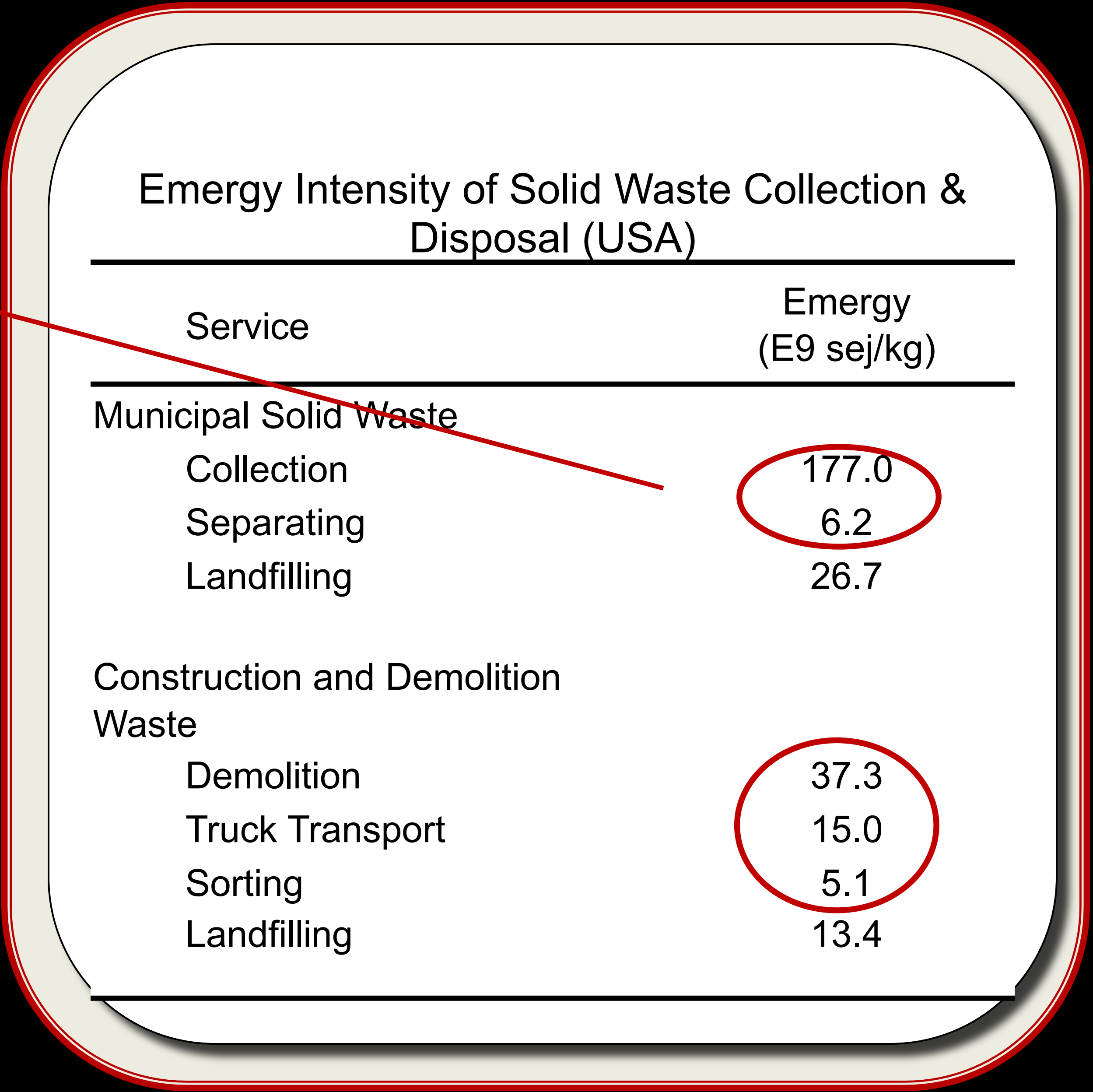
With can recycle



Material Cycles …

> 10% of emergy of materials

> 5% of emergy of materials



Emergy Intensity of Solid Waste Collection & Disposal (USA)

Service	Emergy (E9 sej/kg)
Municipal Solid Waste	
Collection	177.0
Separating	6.2
Landfilling	26.7
Construction and Demolition Waste	
Demolition	37.3
Truck Transport	15.0
Sorting	5.1
Landfilling	13.4

Questions ?