Center for Industrial Ecology
Yale School of Forestry & Environmental Studies

Can We Recycle Our Way Into Sustainability?

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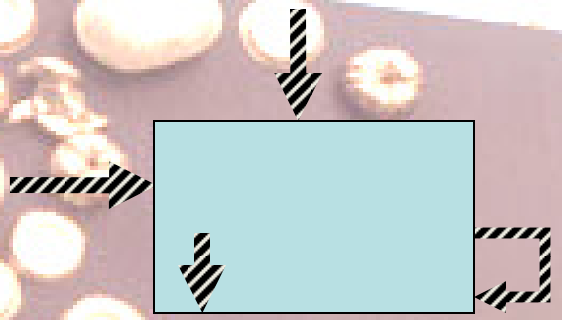
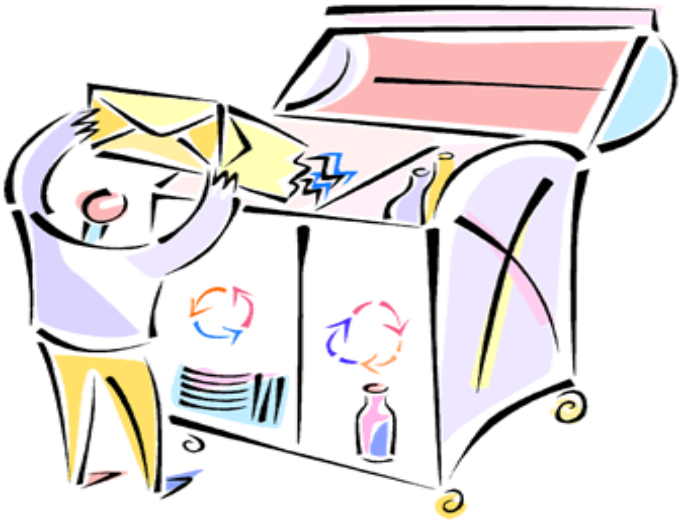


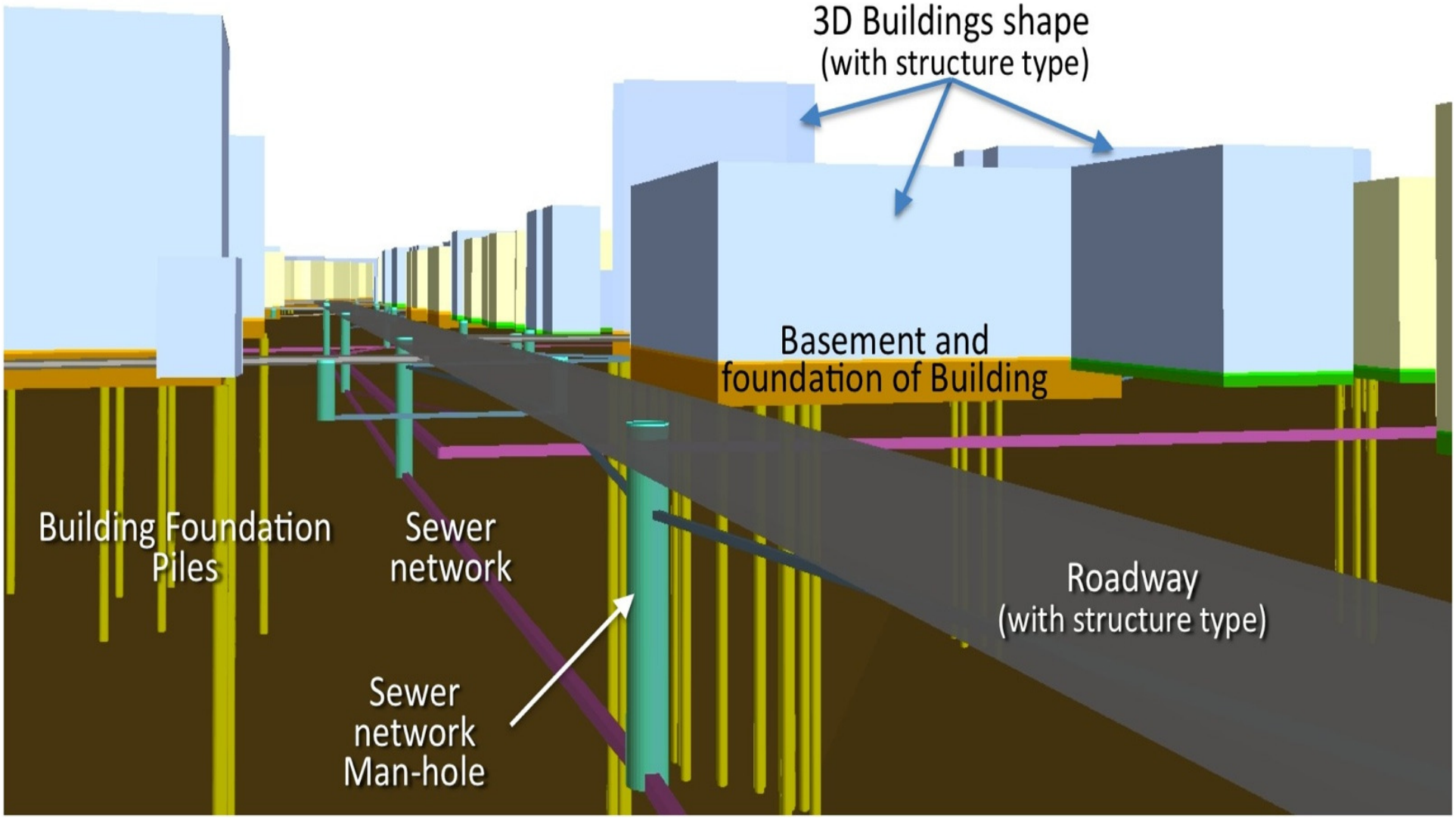
Isn’t Recycling Simple?



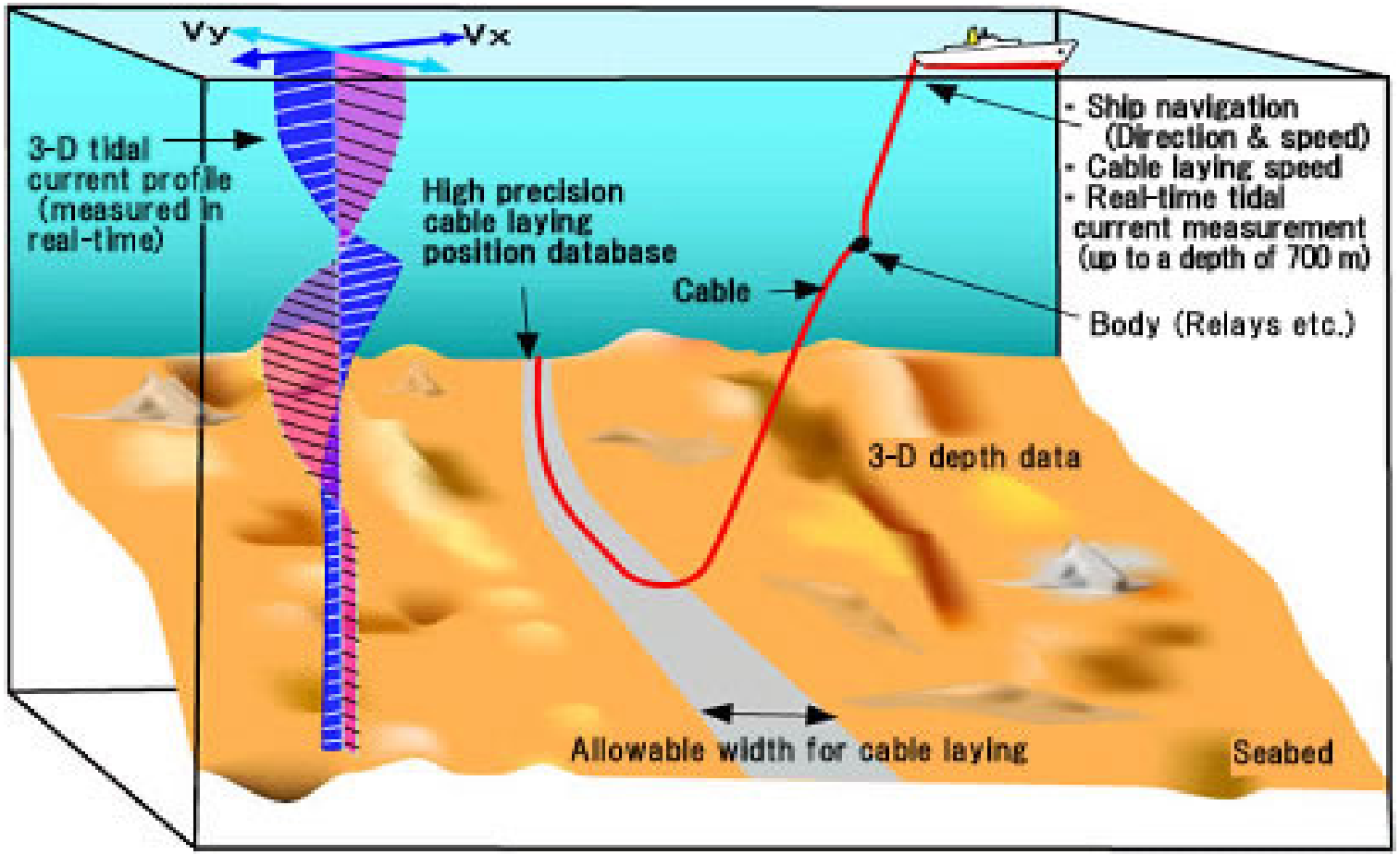
Recycling Challenge #1

Abandoned Stock

Examples of Abandoned Stock



The Laying of Ocean Cable



Courtesy of NTT Marine, www.nttwem.co.jp/english/MAR/MAR-HSS06.htm

Recycling Challenge #2

Comatose Stock

Buried Infrastructure Cables: An Example of Comatose Stock

Courtesy of Midwest Energy, Inc., www.mwenergy.com/gassafety.aspx

Recycling Challenge #3

Dissipative Uses

Brake Linings: An Example of Dissipative Use

Brake linings contain phenolic resin binder, clay and powder fillers, graphite lubricants, and metallic fibers (Ba, Ca, Ti, Cu, Mg, Cr, Sb, Zn, Zr)
Image courtesy of Sansin Brake Co., etrade.daegu.go.kr/.../Brake_Lining.html

Recycling Challenge #4

Hibernating Stock

Computers in the Closet:
An Example of Hibernating Stock

Courtesy of P.C. Surgeon, p-c-surgeon.com/…/computer-disposal.html

Recycling Challenge #5

Lack of Collection

Electronics in the Trash:
An Example of Fragmentary Collection

Courtesy of Gothamist.LLC, gothamist.com/2008/02/16/electronics_rec.php

Recycling Challenge #6

Inadequate Separation

Auto Shredder Output:
An Example of Inadequate Separation

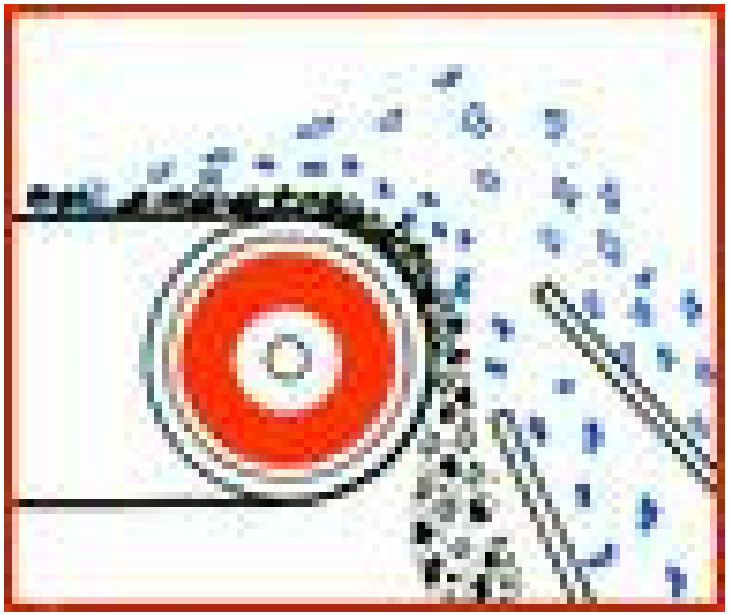
Rubber with cable tree (copper and plastics)

Source: Schaik, A. van 2004, PhD Thesis, TU Delft, The Netherlands

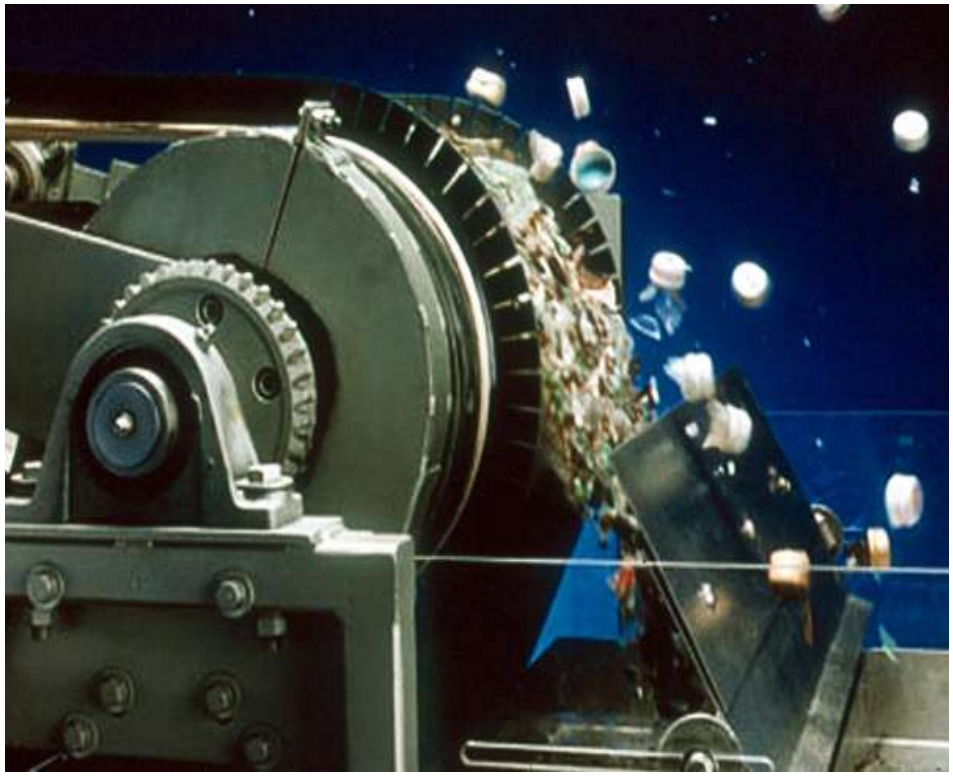
Recycling Challenge #7

Inadequate Sorting

Typical Sorting Technology



Courtesy of Global Equipment Marketing, Inc., www.urangatang.info/~project915/ecseparators.html



Courtesy of ThomasNet, news.thomasnet.com/fullstory/454342

Recycling Challenge #8

Limited Recycling Technology

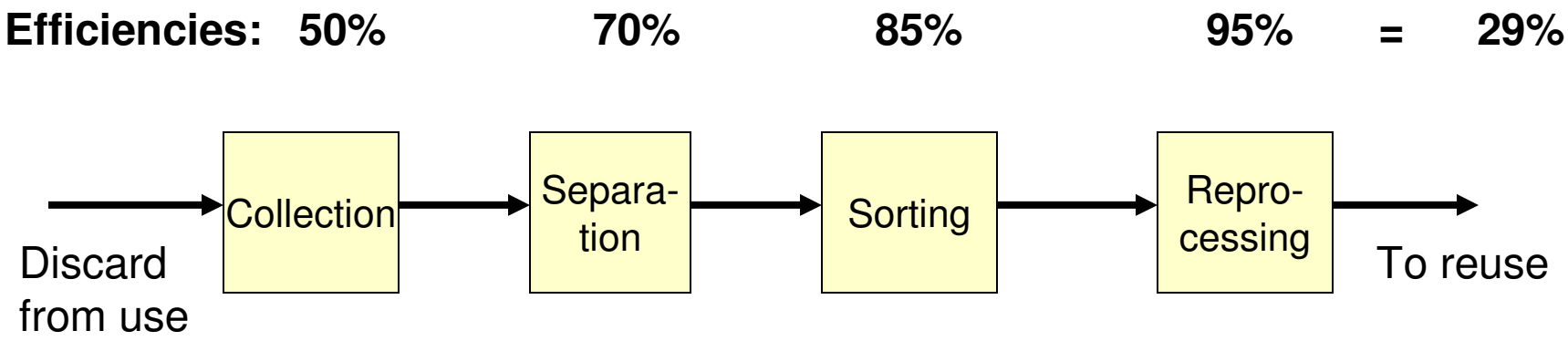
Beginning-of-Life Technology: Populating the Circuit Board

http://video.google.com/videosearch?q=chip+placement&hl=en&emb=0&aq=f#q=circuit+board+placement&hl=en&emb=0

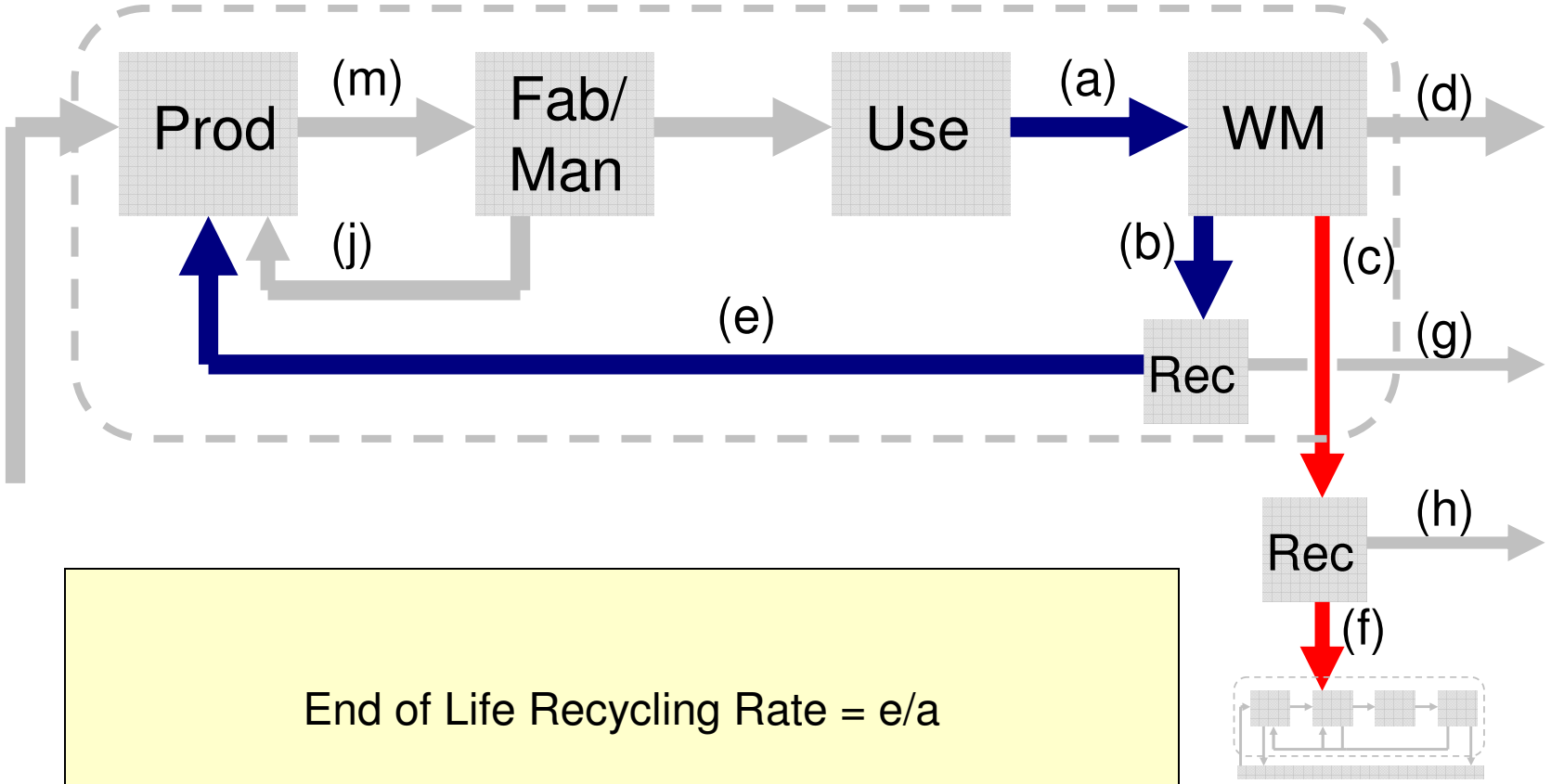
End-of-Life Technology: The Car Shredder

Courtesy of Tradenote.net, www.tradenote.net/keyword/Preshredder/

A Speculative Illustration of End-of-Life Recycling Rate



Material Flows Used for Recycling Rate Calculations



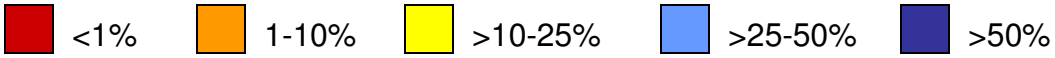
End of Life Recycling Rate = e/a

Recycled Content = (j + e)/m

End-of-life recycling rates for sixty metals

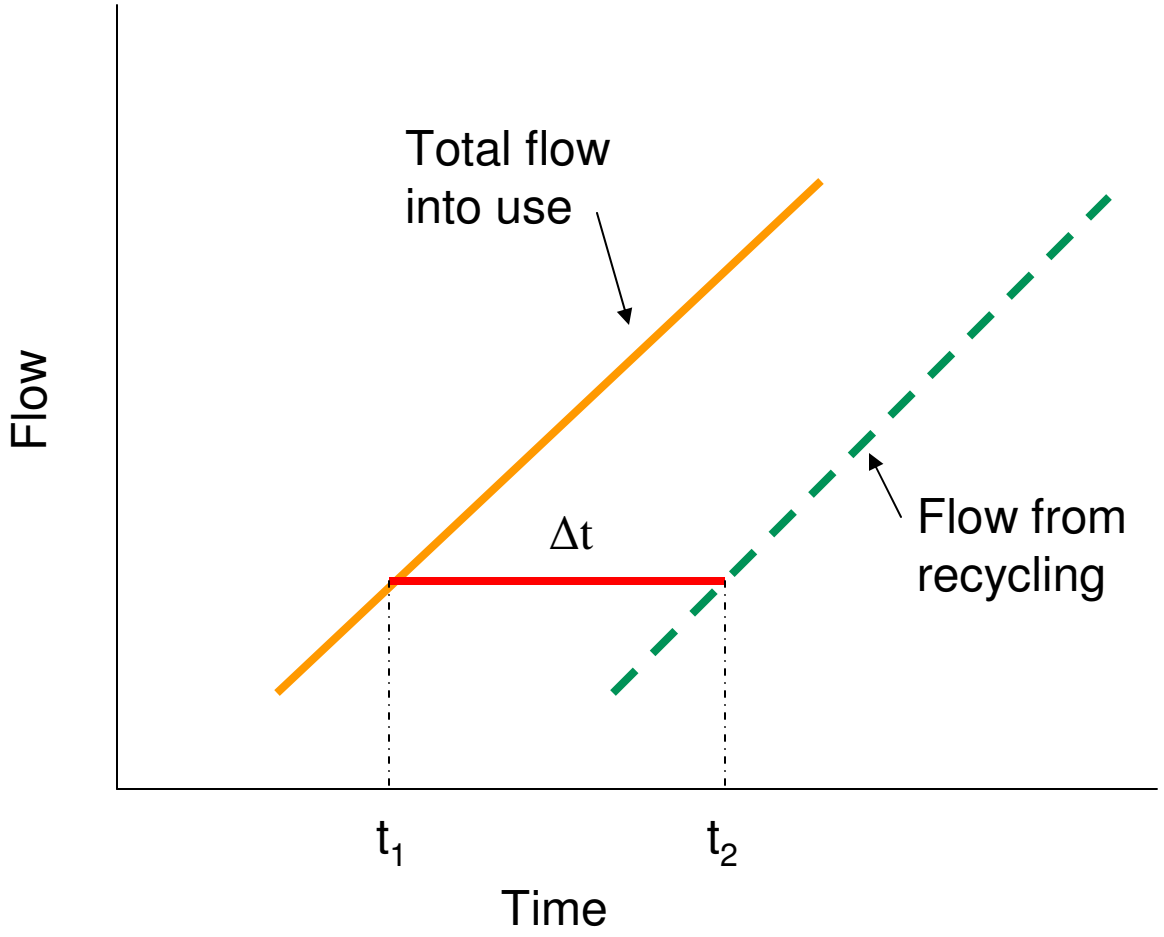
1 H																2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub	113 Uut	114 Uuq	115 Uup	116 Uuh	(117) (Uus)	118 Uuo

* Lanthanides	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
** Actinides	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr



Source: T.E. Graedel et al., *Journal of Industrial Ecology*, in press, 2011

Contributions of Recycling in a Growing Economy



Recycling Conclusions

- Recycling data are very poor, and need to be improved
- Some loss always occurs in processing, and especially in low-tech processing
- Recycling rates of many materials are low or near zero, and may never be high
- **No matter what the effort, we cannot recycle our way to sustainability**