Green Chemistry and Engineering

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Adapted from presentations by E. Beckman (U. Pitt) and J. Brennecke (U. Notre Dame)

12 Principles of Green Engineering

1. Inherent rather than circumstantial
2. Prevention rather than treatment
3. Design for separation
4. Maximize mass, energy, space, and time efficiency
5. Output-pulled versus input-pushed
6. Conserve complexity
7. Durability rather than immortality
8. Meet need, minimize excess
9. Minimize material diversity
10. Integrate local material and energy flows
11. Design for commercial afterlife
12. Renewable rather than depleting

From Paul Anastas

Inherent Rather than Circumstantial / Prevent Rather than Treat

A Case Study:

Polyacrylamide vs. Poly (N-vinyl) Formamide

Used in papermaking, oil recovery, personal care products, water treatment

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Acrylamide	**(N-vinyl) formamide**
Highly toxic, causes CNS paralysis	Low toxicity, not a neurotoxin

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Highly toxic, causes CNS paralysis	Low toxicity, not a neurotoxin
Green enzymatic synthesis	Synthesis uses hydrogen cyanide
~ $1/kg	~ $4.50/kg

Conserve Complexity / Minimize Excess

- **IBM PC's used to be made with 15 different types of screws (unnecessary complexity)**
- **Replaced with 1 type of screw**
- **Easier to disassemble & recycle**

Diana Bendz, IBM
Presentation at ND, 2000

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  - **Make modular to replace processors, memory**

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- **Replaced with 1 type of screw**
- **Easier to disassemble & recycle**
- **Why not reuse computers?**
  - **Make modular to replace processors, memory**
  - **Economic…**

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Presentation at ND, 2000

Durability Rather Than Immortality

Example: CFC's

- $C_xH_yF_zCl_q$
- Non-flammable
- Non-toxic
- Inexpensive
- Effective
- Stable

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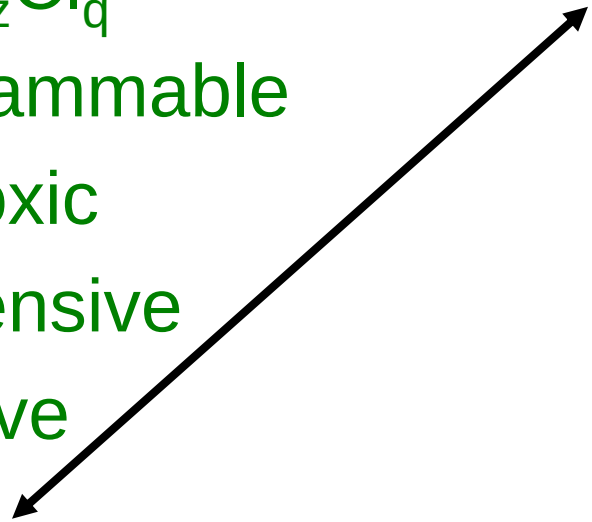
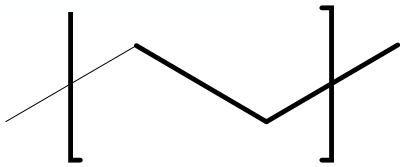


- Long-lived, migrate to upper atmosphere
- UV-induced fragmentation in upper atmosphere leads to ozone depletion

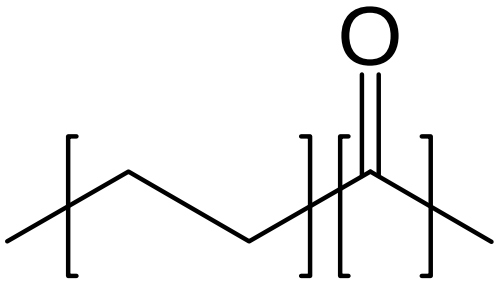
Durability Rather Than Immortality / Design For Commercial Afterlife

Example: Packing materials



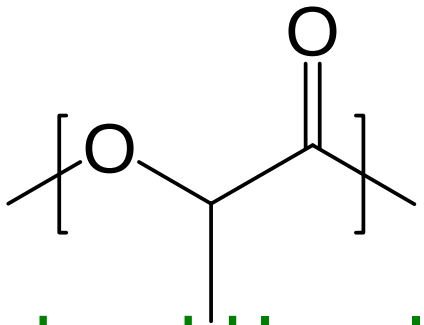
Polyethylene, packaging

Vs.



Photodegradable analog

Vs.



Biodegradable analog

Differences in cost, density, and energy intensity

Design for Separation

Design for Separation, the Serendipitous Result…..

Polypropylene Cap (sometimes present…)

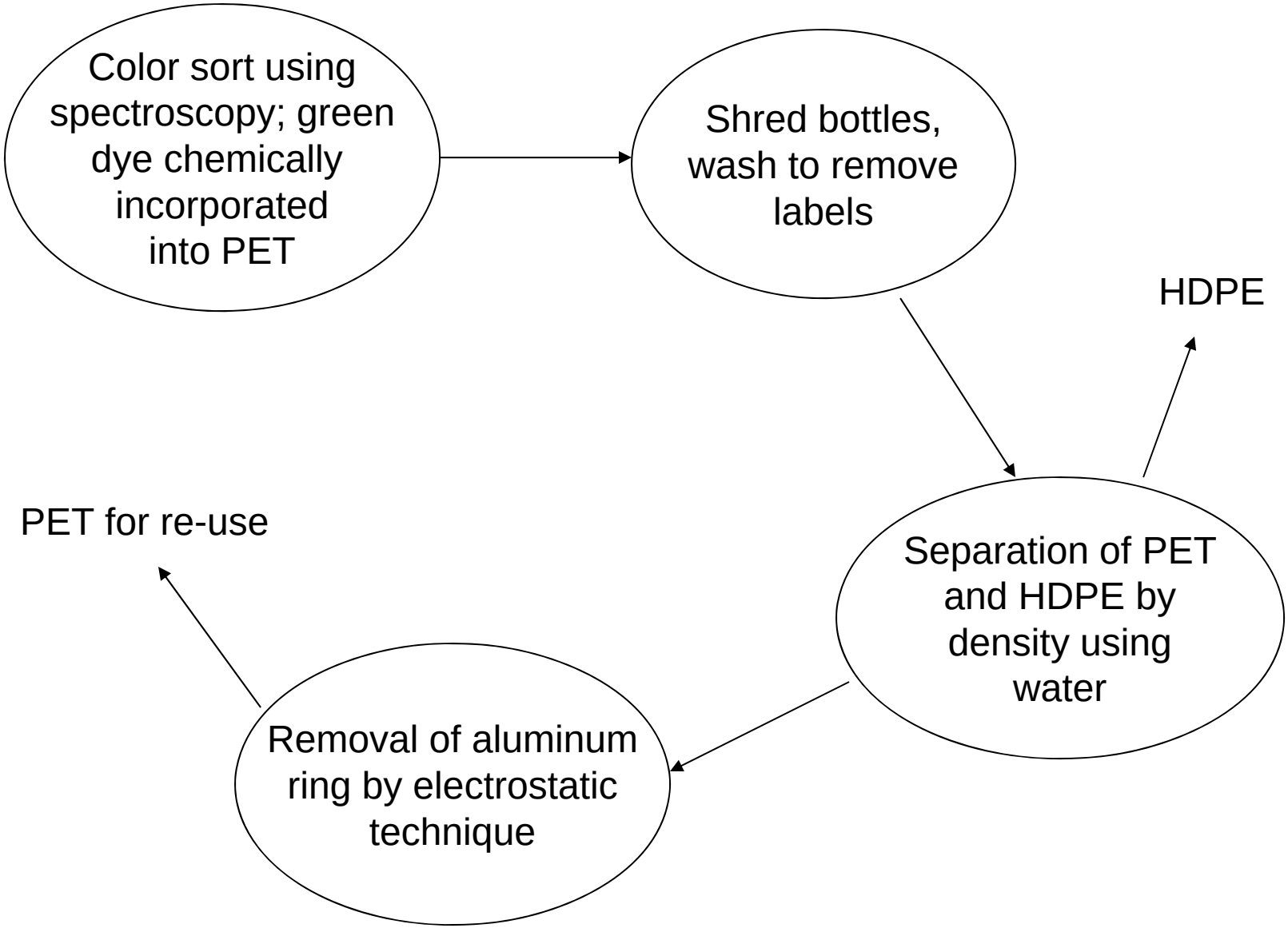
Aluminum Ring

Polyethylene Terephthalate Bottle

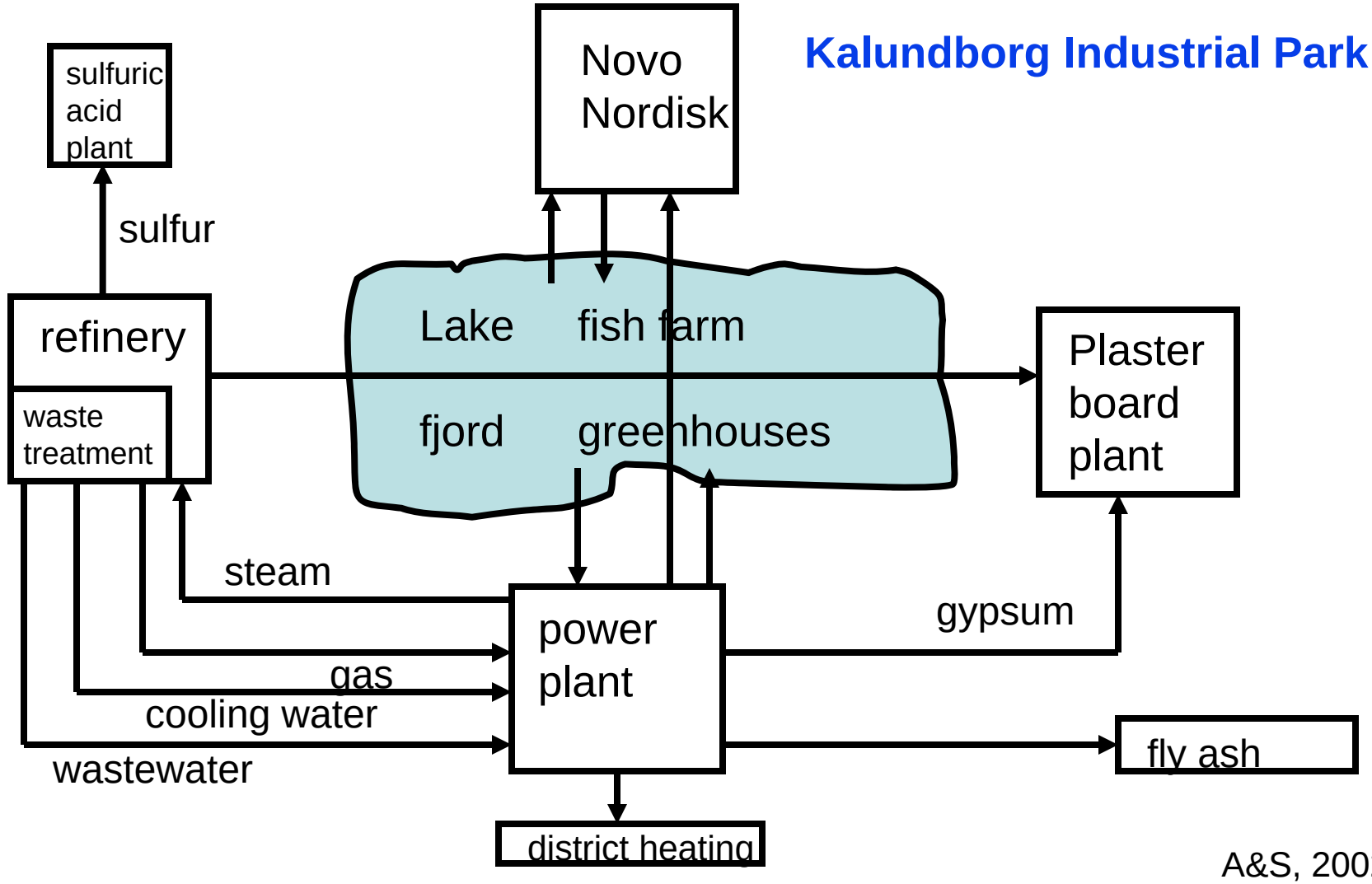
Paper/adhesive Label

Polyethylene Base Cup

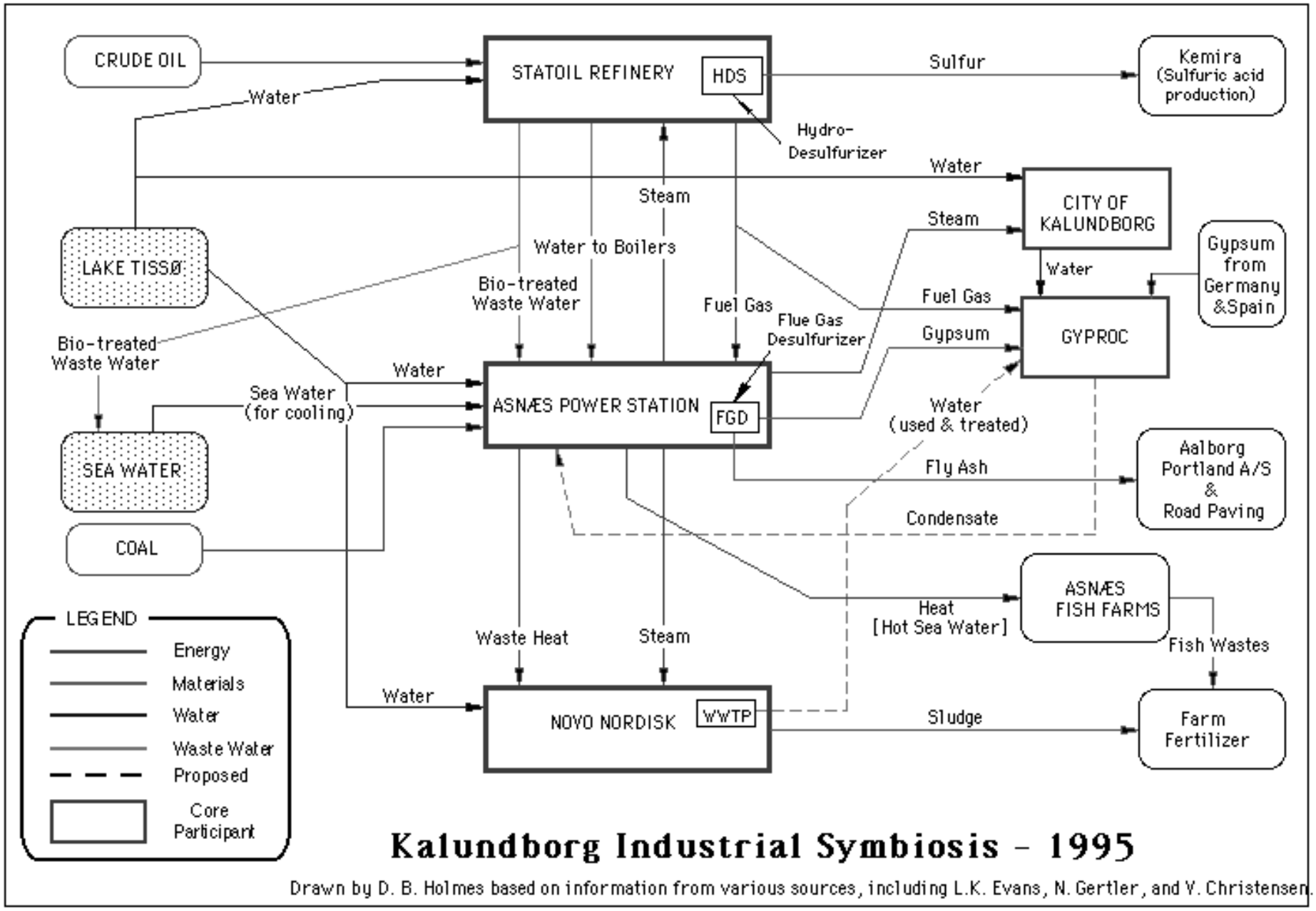
Recycling of PET bottles



Integrate Material and Energy Flows / Maximize Efficiency



A&S, 2002



Kalundborg Industrial Symbiosis – 1995

Drawn by D. B. Holmes based on information from various sources, including L.K. Evans, N. Gertler, and Y. Christensen.

My Research Interests

- **Ionic liquids**
  - **Non-volatile alternative solvents**

    “Prevent rather than treat”
- **Nanoporous materials**
  - **Selective separations**
    - **Water purification**
    - **Heavy metal capture**
  - **Targeted sensing materials**
- **“Greenness Factor” – assessment tools**

References

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- Allen and Shonnard, Green Engineering, 2002, Prentice-Hall
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- Segars et al., ES&T, 2003, 37, 5269.