

The Twelve Principles of Green Engineering*

1. Inherent Rather Than Circumstantial

Designers need to strive to ensure that all materials and energy inputs and outputs are as inherently nonhazardous as possible.

2. Prevention Instead of Treatment

It is better to prevent waste than to treat or clean up waste after it is formed.

3. Design for Separation

Separation and purification operations should be designed to minimize energy consumption and materials use.

4. Maximize Efficiency

Products, processes, and systems should be designed to maximize mass, energy, space, and time efficiency.

5. Output-Pulled Versus Input-Pushed

Products, processes, and systems should be "output pulled" rather than "input pushed" through the use of energy and materials.

6. Conserve Complexity

Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse, or beneficial disposition.

7. Durability Rather Than Immortality

Targeted durability, not immortality, should be a design goal.

8. Meet Need, Minimize Excess

Design for unnecessary capacity or capability (e.g., "one size fits all") solutions should be considered a design flaw.

9. Minimize Material Diversity

Material diversity in multicomponent products should be minimized to promote disassembly and value retention.

10. Integrate Material and Energy Flows

Design of products, processes, and systems must include integration and interconnectivity with available energy and materials flows.

11. Design for Commercial "Afterlife"

Products, processes, and systems should be designed for performance in a commercial "afterlife."

12. Renewable Rather Than Depleting

Material and energy inputs should be renewable rather than depleting.

* Anastas, P.T., and Zimmerman, J.B., "Design through the Twelve Principles of Green Engineering", *Env. Sci. and Tech.*, 37, 5, 95 ? 101, 2003.