ENVIRONMENTAL IMPACTS OF 3-D PRINTING

Bob Olson Institute for Alternative Futures December 13, 2013

Complex Objects



Small Variations on a Basic Design



Short-Run Manufacturing



One-of-a Kind Objects





Bio-printing







Biopaper

Bioink

Bioprinter



Producing Parts When & Where Needed



Public Access Design Libraries





Hobby Printing



Speed & Cost



Carl Bass, President of Autodesk

Third Power Law of 3-D Printing

"If we want something twice as big, it will cost 8 times as much and take 8 times as long to print. If we want Something 3 times as big, it will cost

about 27 times more and take 27 times longer to print. And so on."







The Cube 3-D Printer \$1,299 at Staples

Concept Laser's X line 1000r Metal Additive Manufacturing Machine ~\$1,000,000

Life Cycle Analysis

UC-Berkeley Mechanical Engineering Department

- Material extraction & processing
- Manufacturing of the 3-D printers
- Transportation
- Energy use in operation
- Material in the final parts
- Material wasted
- End-of-life disposal of machines







A Key Finding

The best way to minimize environmental impacts is to:

"... have the fewest number of machines running the most jobs each... Job shops legitimately can argue that they provide both economic and environmental advantage to their customers."

Do 3-D Printers Waste Less Material?

- Fused Deposition Modeling (FDM) can be nearly waste-free
 - But users sometimes run several copies to get the best print
 - Waste is generated when support materials are needed
- Industrial printers that use powdered or molten polymers leave a substantial amount of material in the print bed
- Selective Laser Sintering machines use only part of the metal in their powder beds – require 20-50% virgin material for good prints



Are 3-D Printers More Energy Efficient?

This...



uses 100s of times more energy than traditional methods like casting and machining.

Also, materials used have high "embedded energy."

Do 3-D Printers Reduce Transportation Energy Use?











ABS plastic is easily recycled PLA plastic is biodegradable



Filabot Reclaimer





Recycling Programs

A Unique Issue: Solid Multi-Material Designs









Where Will Things Be Made?



Will We Overprint?

A New Model of Sustainable Consumption

- Print When Needed
- Replace Parts
- Upcycle
- Customize



A New Level of Wasteful Consumption

- Instant Gratification
- Trivial Knick Knacks
- Multiple Drafts



A Governance Challenge



OF





- Ensure the sustainability of 3-D printer production. Develop manufacturing processes that use energy and materials efficiently, use renewable resources where possible and treat waste and pollution as design failures.
- **Design 3-D printers for energy and resource efficiency**. Strive for continuous improvement in printer design to allow more energy-efficient operation, prevent material waste, improve durability, and allow easy repair and upgrading.
- Use Renewable and/or Recyclable Feedstocks. Feedstocks should be renewable and biodegradable whenever technically and economically practicable. When that is not possible, use easily recyclable feedstocks and insure they are properly recycled.



- **Design both 3-D printers and feedstocks for safe and healthy operation**. Minimize dangers of exposure to high ultrafine particle (UFP) concentrations, fine metal powders, and toxic materials of any kind.
- **Recycle Printers and Materials**. Provide product take-back and recycling of 3-D printers, recycling of used feedstock cartridges, canisters, and spools and recycling of discarded printer products.
- Educate Users on Green 3-D Printing. Provide easy-tounderstand information to users on safe operation, minimizing UFP exposure, using features that improve energy efficiency and minimize waste, and doing cleaning and other maintenance needed to minimize environmental impacts. Promote sustainable consumption over frivolous use.

Could 3-D Printing Be Really Big?



Early Over-Enthusiasm	Disillusionment	The Real Revolution
Internet Boom - 1990s	Internet Bust ~ 2000 (Google just starting)	\$\$ Multi-hundred Billion Internet Companies