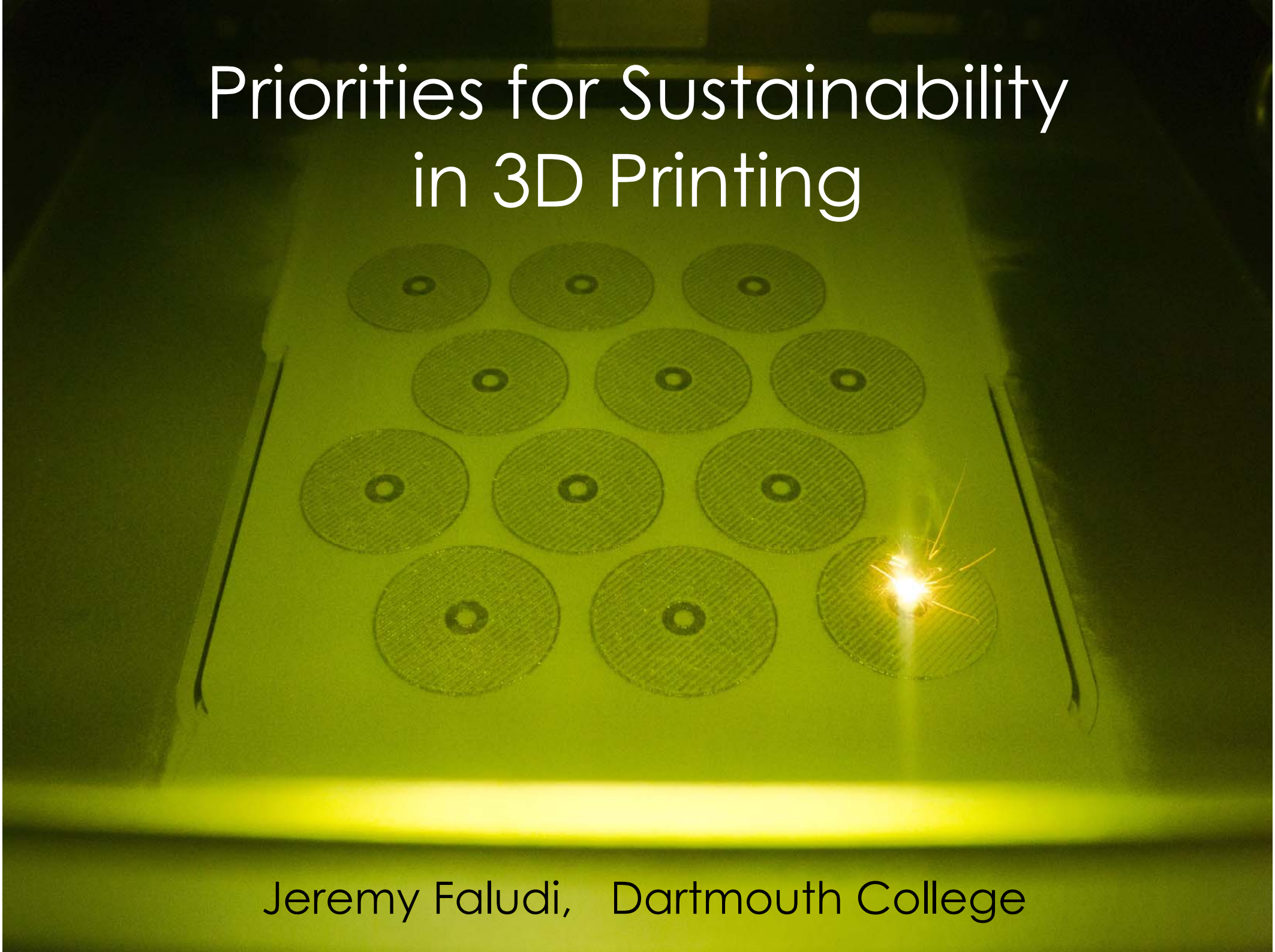
# Priorities for Sustainability in 3D Printing



Jeremy Faludi, Dartmouth College

# Printing Process Variety




images from renishaw.com, 3Dsystems.com, stratasys.com, afinia.com, typeamachines.com, engadget.com

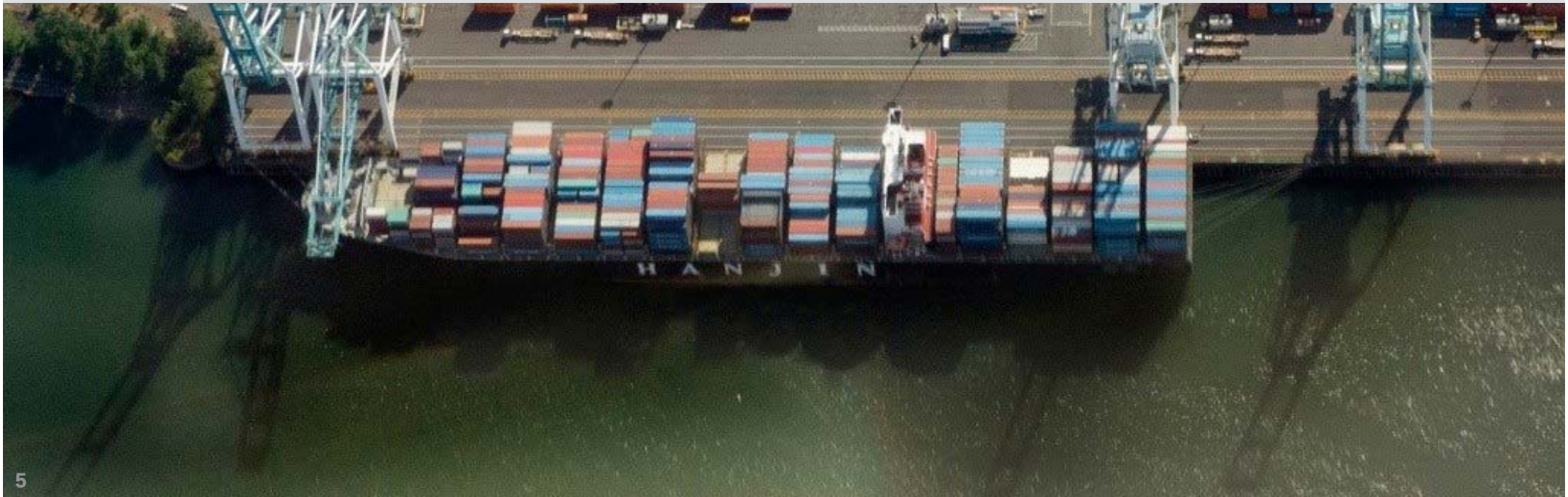
# The Next Production Revolution

## IMPLICATIONS FOR GOVERNMENTS AND BUSINESS

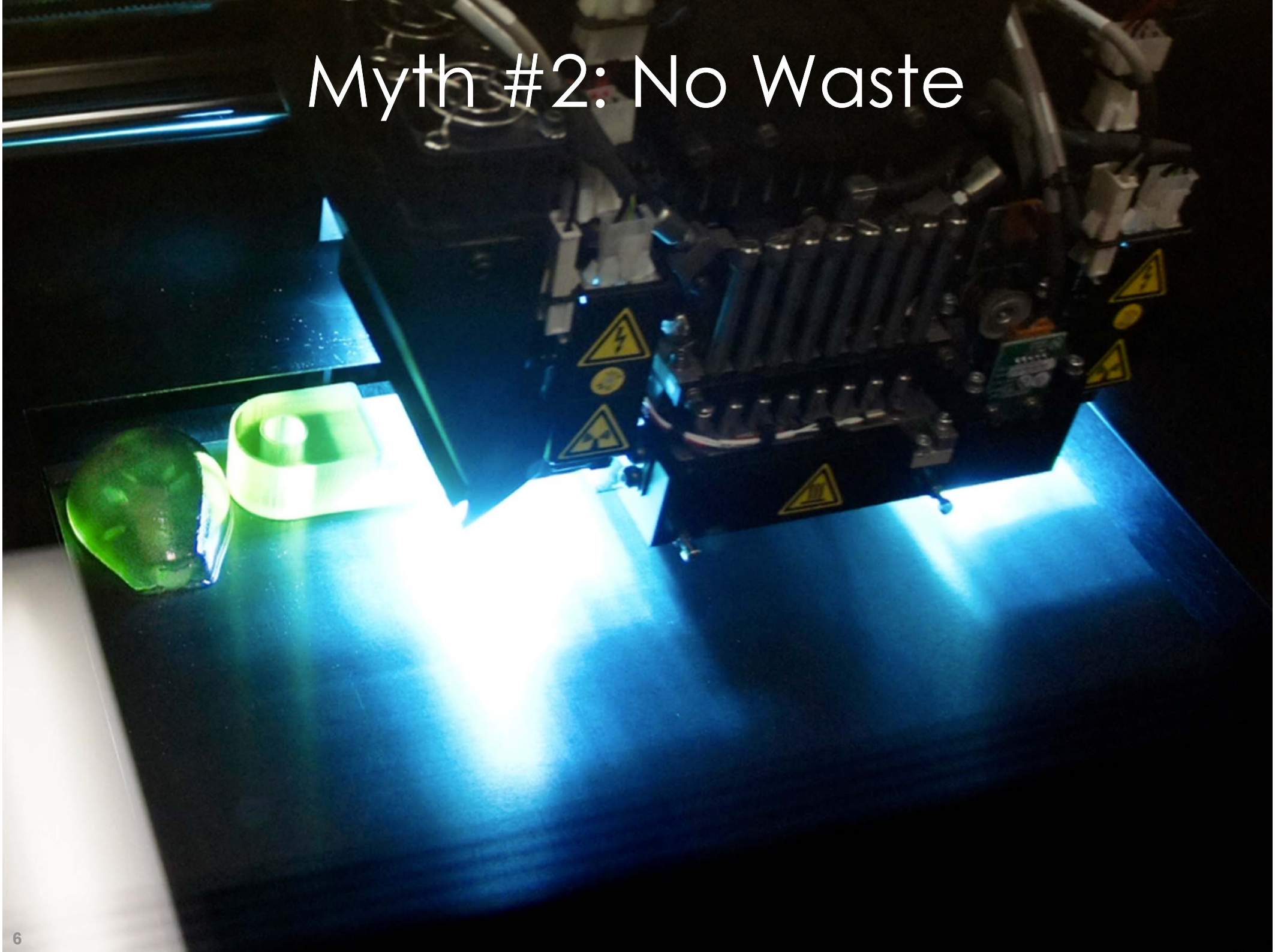
OECD

# 3D Printing Myths vs. Facts

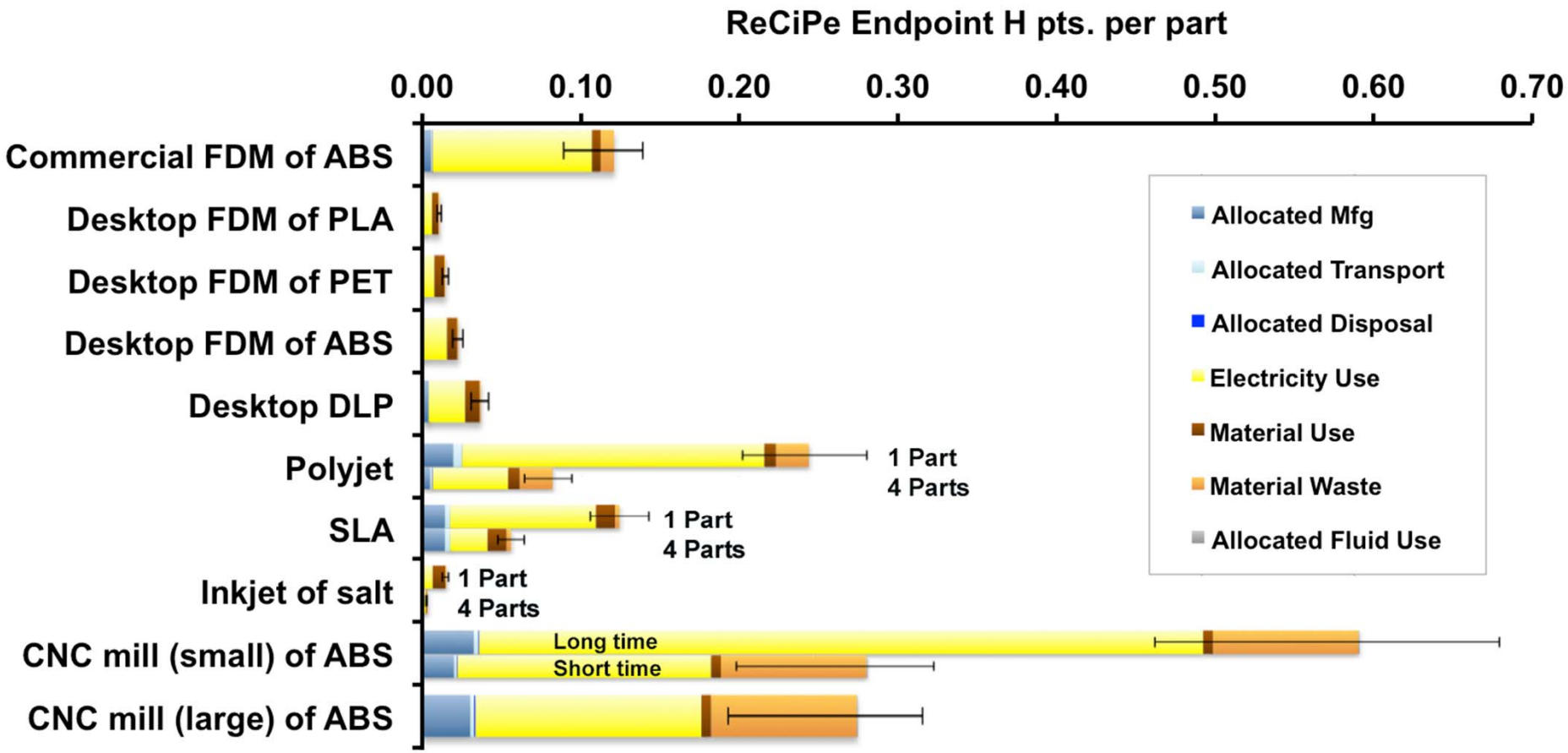
# Myth #1: No Transportation



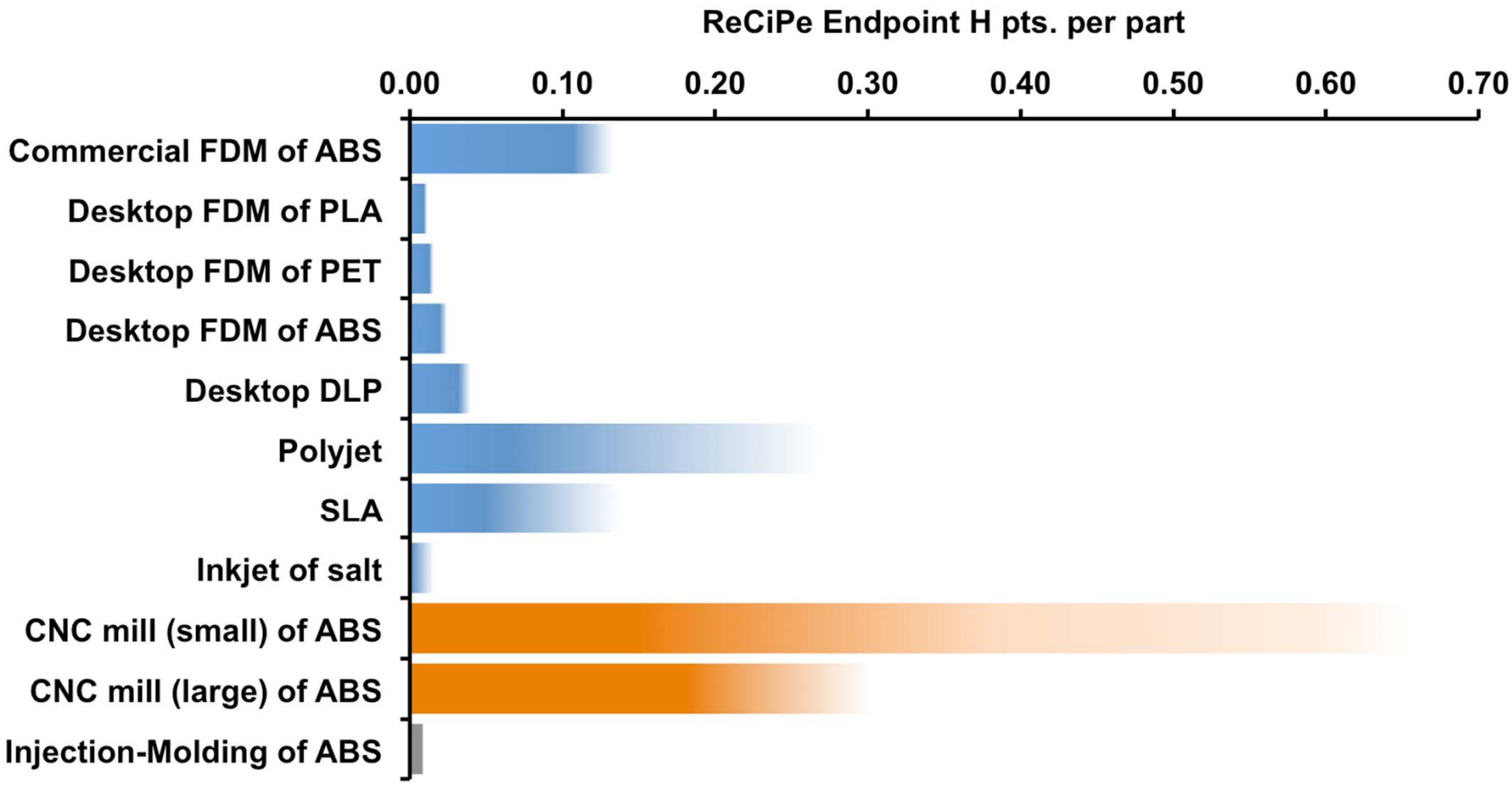
# Myth #2: No Waste



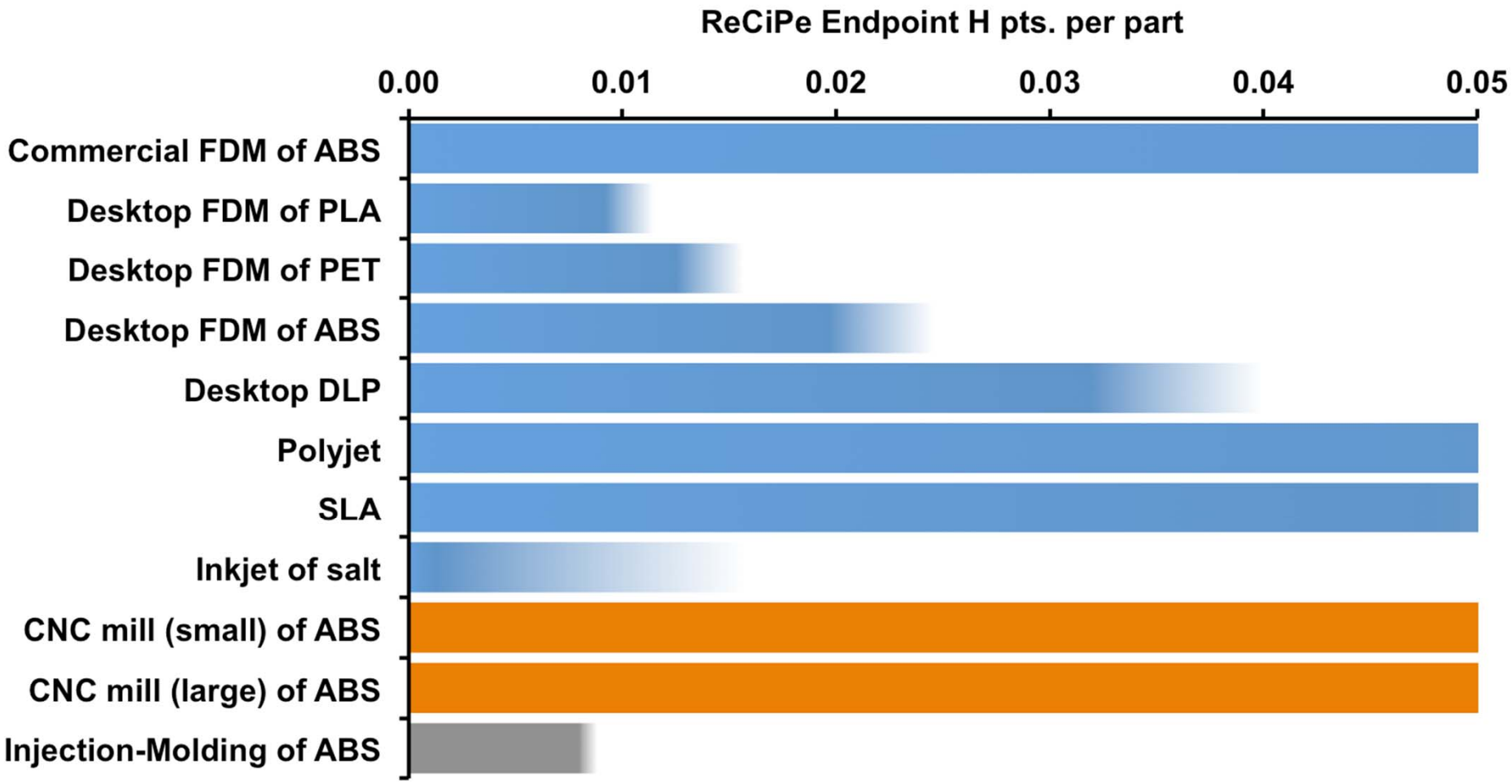
# Energy is Main Impact



# Comparisons: Printing 24/7



# Comparisons: Printing 24/7



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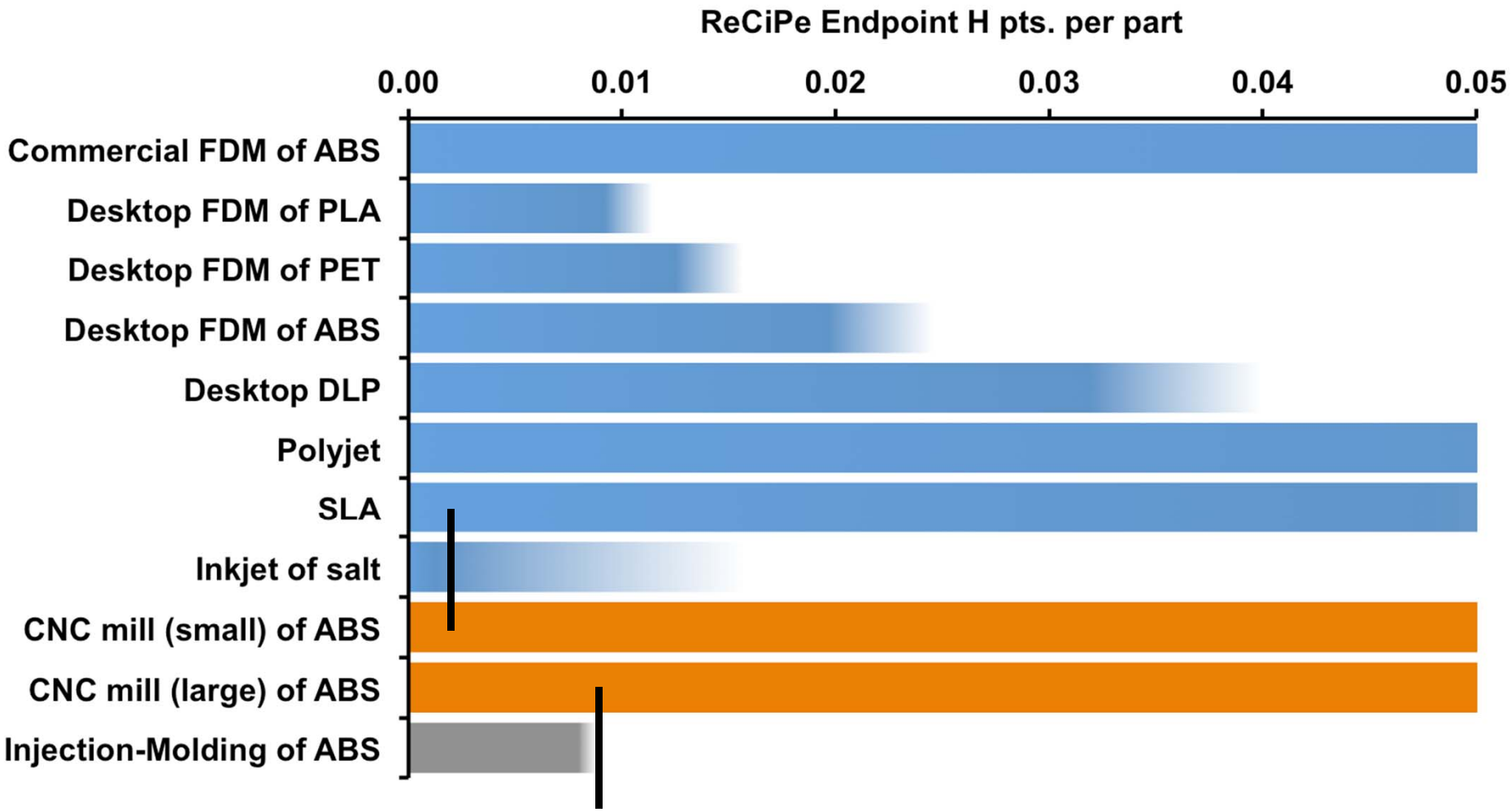


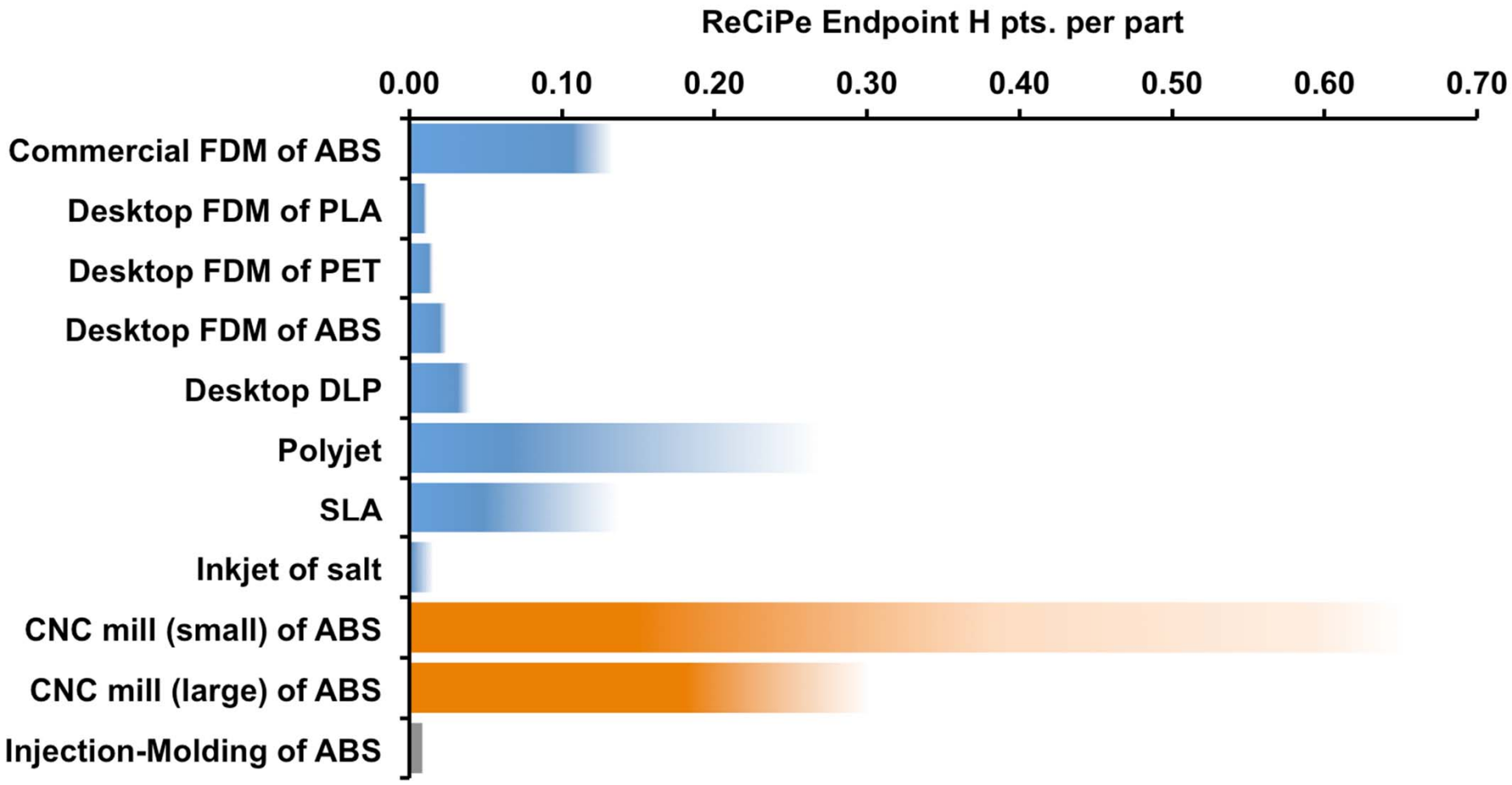
# Is 3D Printing Green? It Depends…



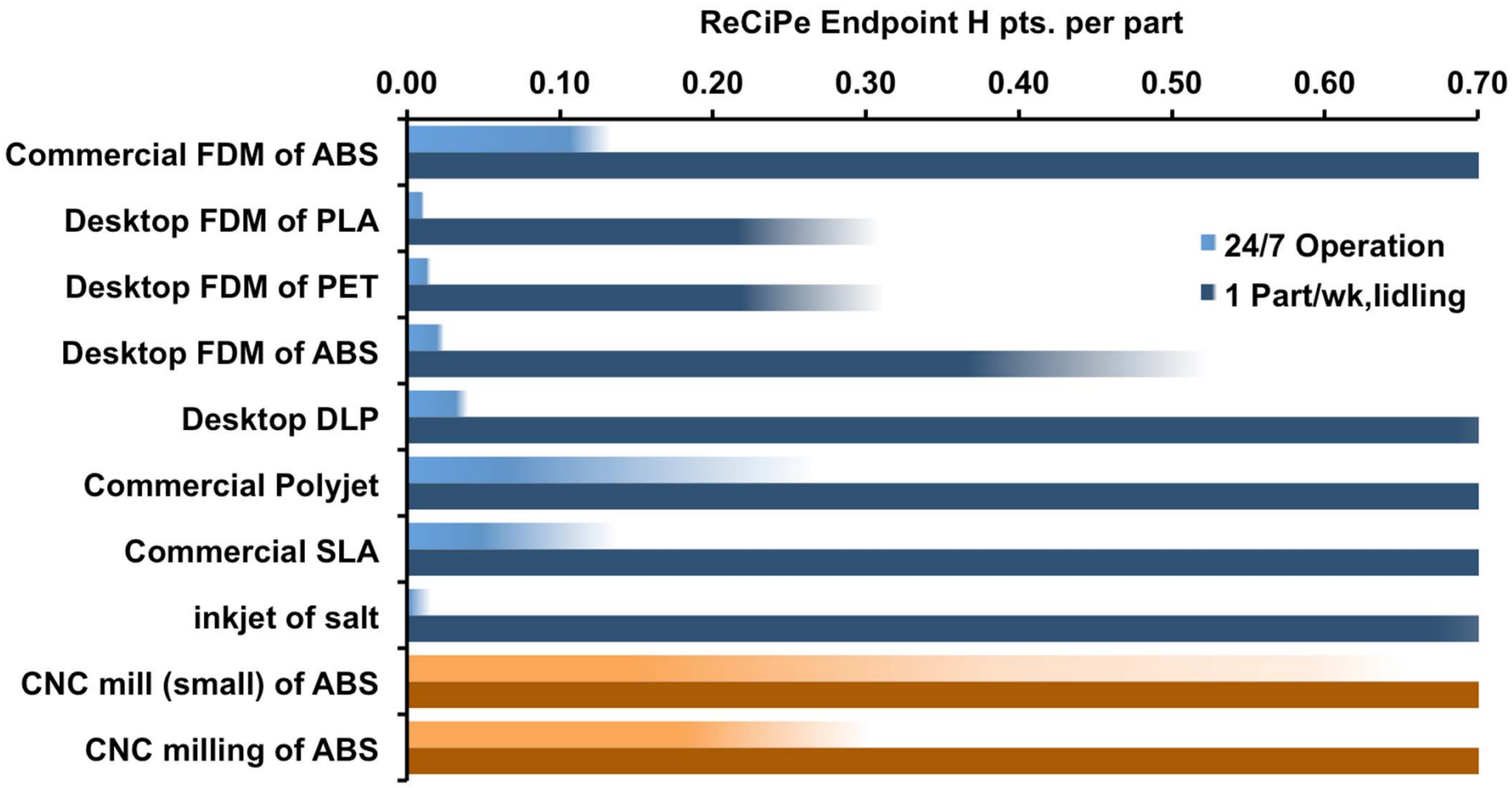

images from renishaw.com, 3Dsystems.com, stratasys.com, afinia.com, typeamachines.com, engadget.com

# Is 3D Printing Green? It Depends…

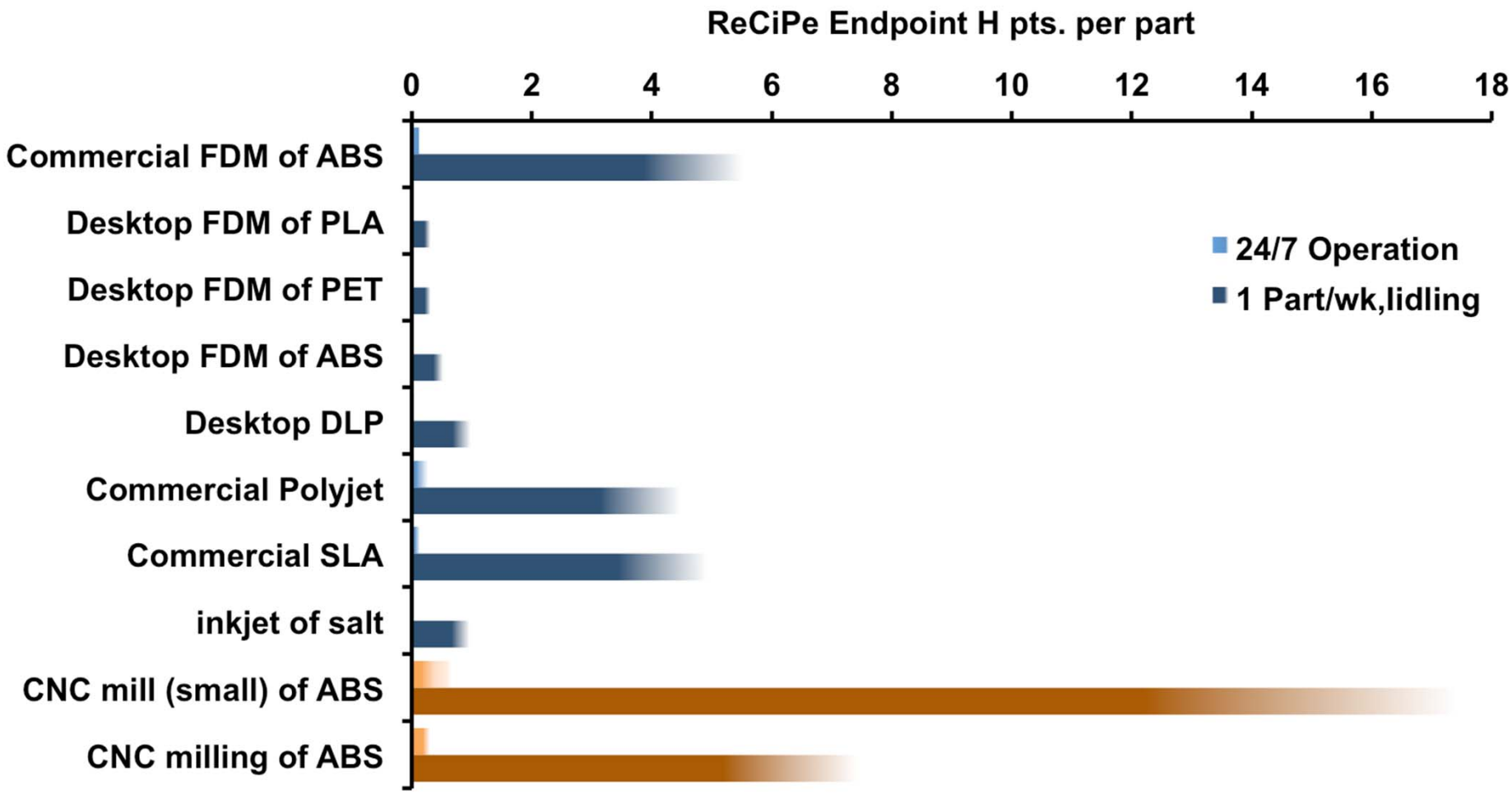
# Utilization



# Utilization



# Utilization



# Obstructing Circular Economy

# Irreversible Materials

# Mixing Materials Inseparably

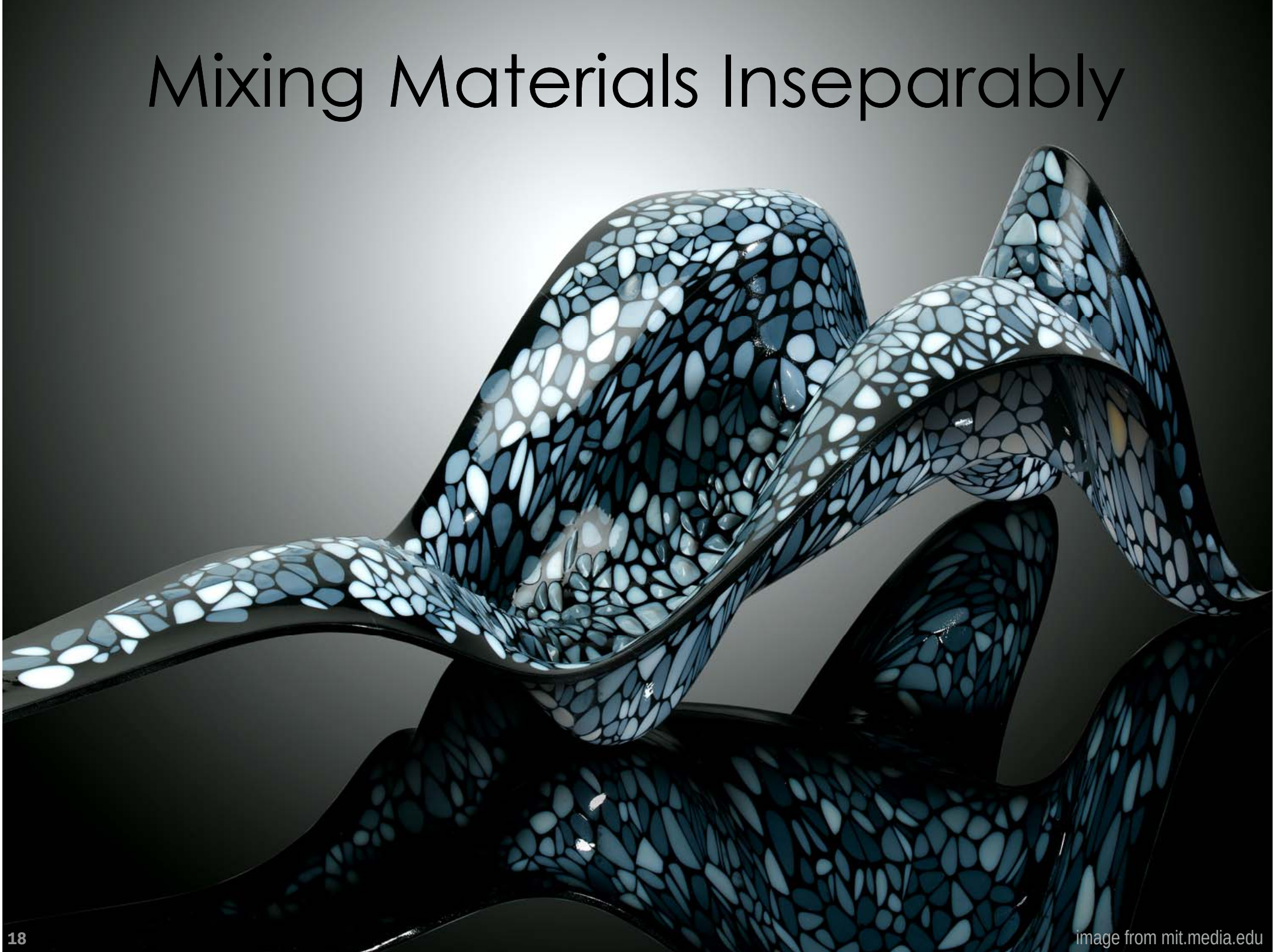




image from mit.media.edu

# Enabling Circular Economy

# Enable Green Materials?



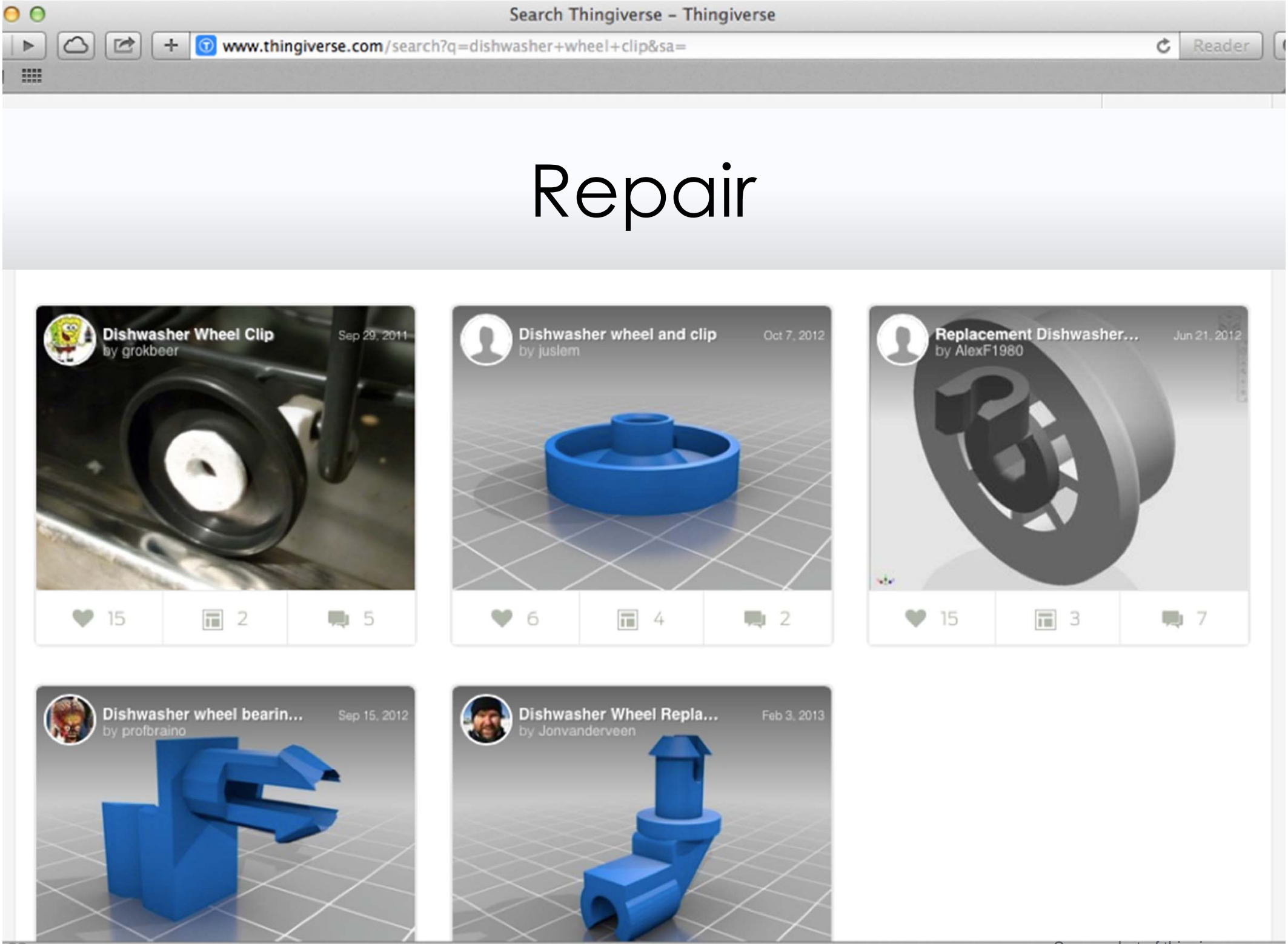
image from mit.edu

# Enable Green Energy?

image from doorsofperception.com

# Efficient Vehicles

image from bloomberg.com






Screen shot of thingiverse.com

# Democratize Production


image from 3dprintingindustry.com

# Align Economic Incentives

# Align Economic Incentives

Material use = $

Complexity ≈ free

# Align Economic Incentives

Energy use = $

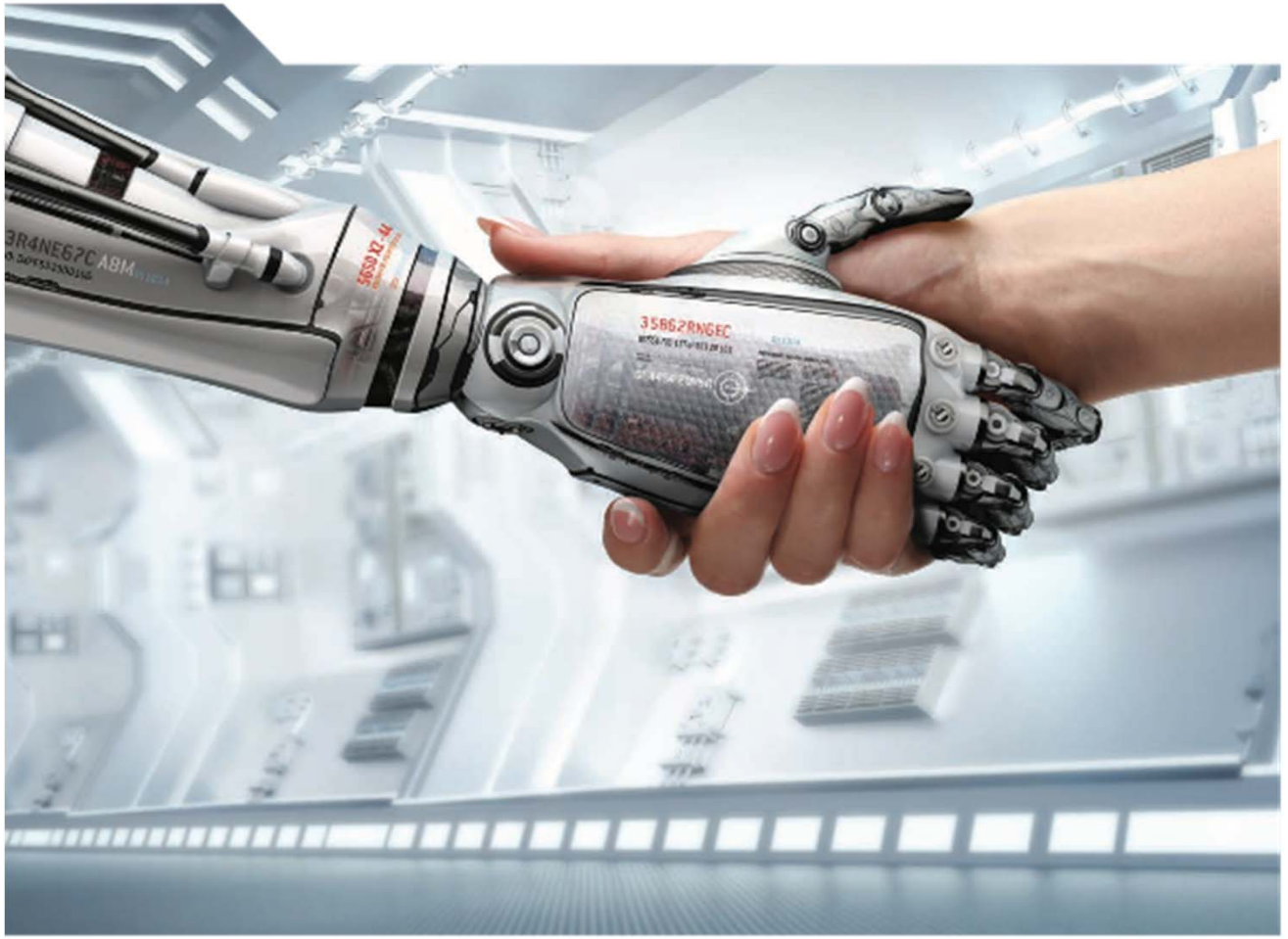
Complexity ≈ free

# Green 3D Printing Possibilities

- Align economic incentives
- Efficient vehicles
- Democratize production
- New materials?  Clean energy?
- Repair?

# The Next Production Revolution

## IMPLICATIONS FOR GOVERNMENTS AND BUSINESS

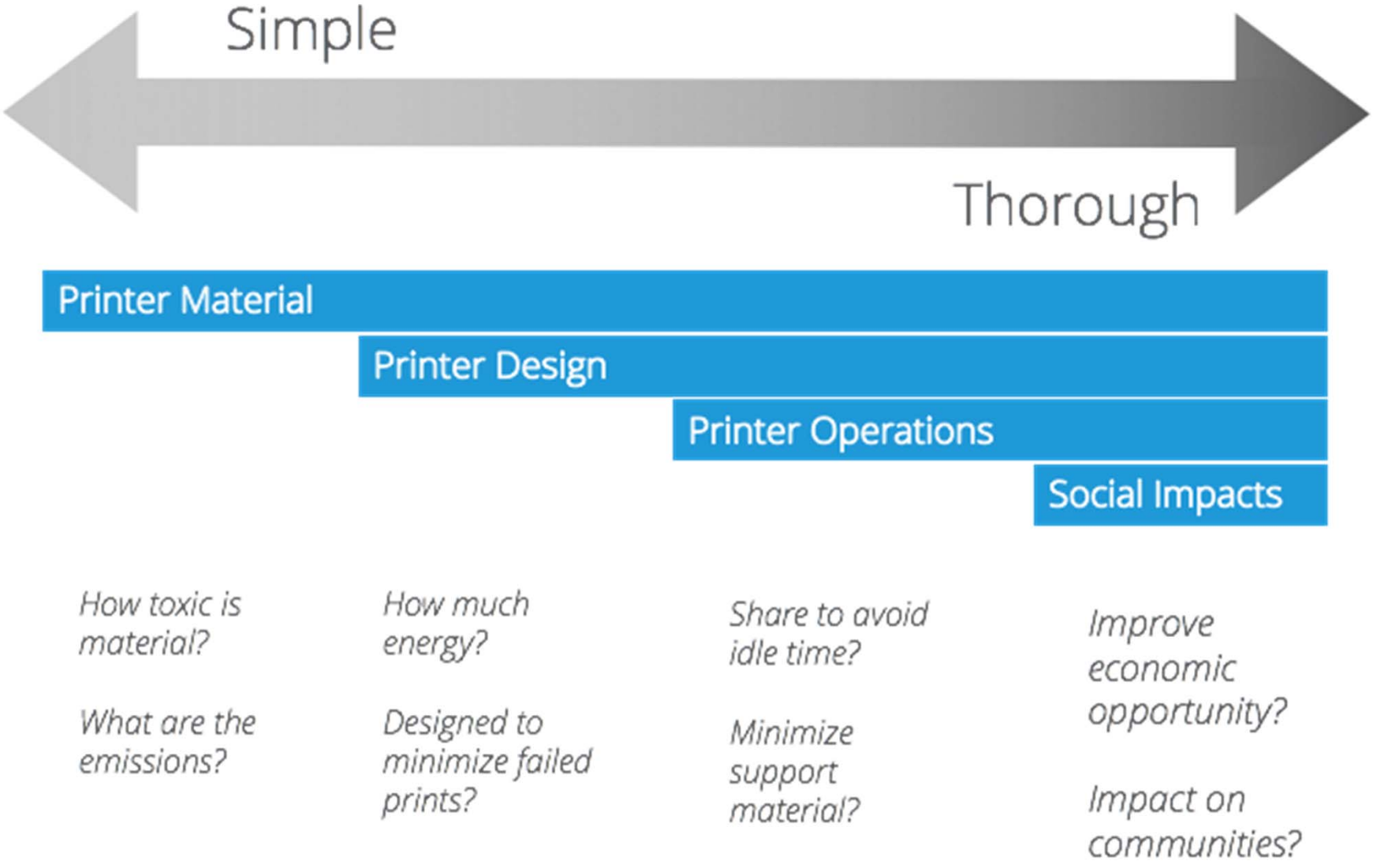


OECD

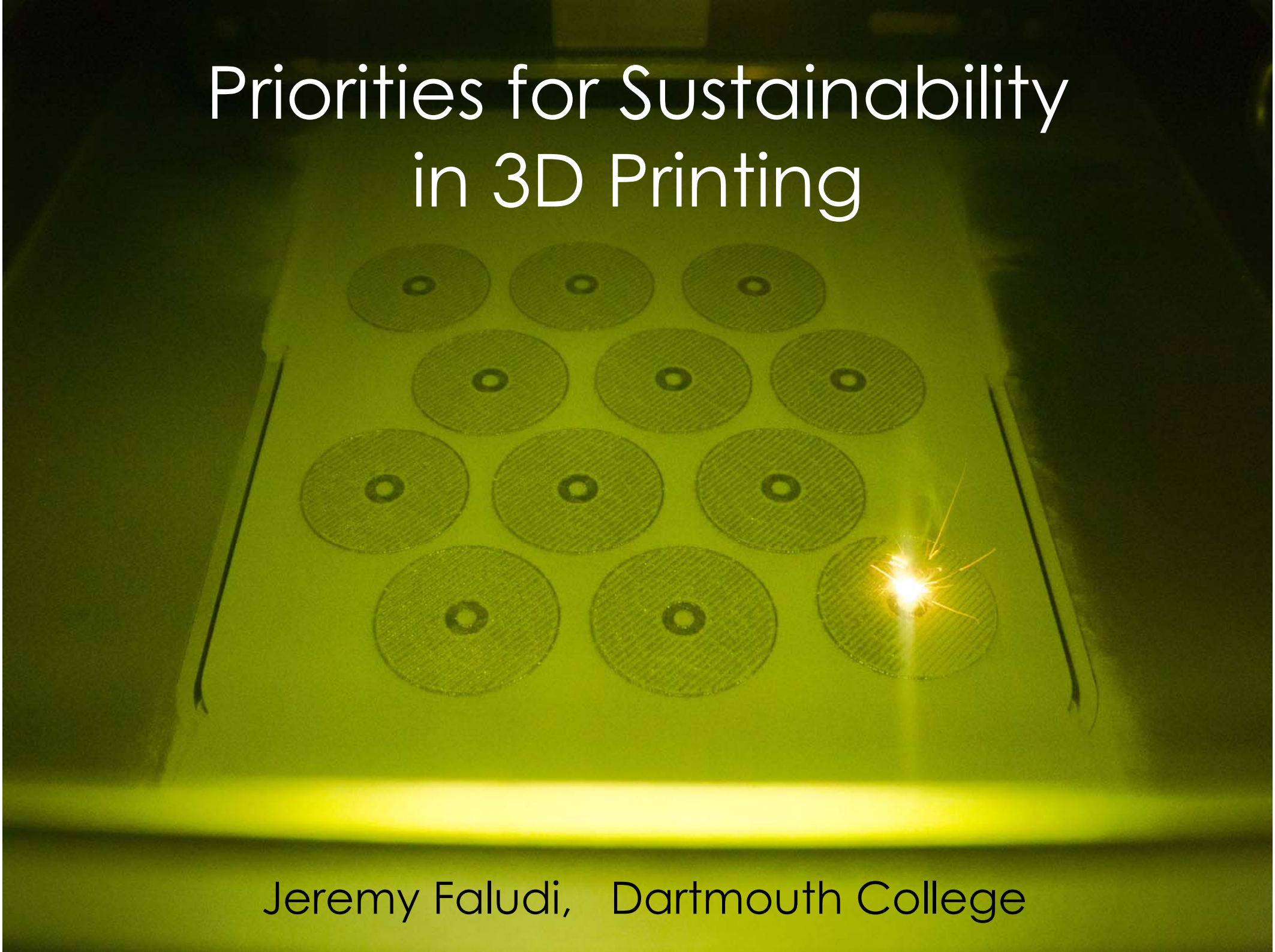
Table 5.3. **Priorities for improving environmental impacts of 3D printing**

| Focus area | High priority | Medium priority | Low priority |
|---|---|---|---|
| Printer design | **1. Design for minimal idle time (ease of sharing, minimal set-up/clean-up time)**<br>High leverage and simple to implement.<br><br>**2. Automatic low-power standby**<br>High leverage and simple to implement. | **1. Low-energy printing process (chemical bonding, not melting)**<br>Moderate to high leverage, but requires significant investment and must be combined with energy-efficient equipment systems.<br><br>**2. Energy-efficient equipment systems (insulation, motors, electronics)**<br>High leverage, but requires significant investment. | **Design software and hardware to minimise material use and waste**<br>High leverage, but market incentives already exert pressure in this direction. |
| Printing materials | **1. Non-toxic, compostable photopolymers for SLA, DLP, PolyJet, CLIP printers**<br>High leverage and large installed base of photopolymer printers.<br><br>**2. Improved physical performance/print quality/compostability for existing biopolymers in low-energy print processes**<br>Commercialising existing materials requires less investment than developing new materials. | **Chemical bonding (not melting) of compostable biopolymers, such as MIT's WBDF, for extrusion printers**<br>High leverage, but requires replacing or retrofitting existing extrusion printers (more expensive than simply replacing chemicals in photopolymer printers). | **1. Tunable material properties through printing process, for all printers**<br>Leverage uncertain, still experimental. Could simplify recycling, composting, and toxicity screening, but requires significant investment.<br><br>**2. Infinitely reusable metal powders produced from recycled material**<br>Probably lower leverage than reducing energy use, and probably requires significant investment. |
| Printer operations | **1. Sharing printers for more utilisation of fewer machines**<br>High leverage and simple to implement.<br><br>**2. Optimal bed packing for photopolymer, inkjet, and laser sintering printers**<br>High leverage and simple to implement. | **Minimising support material for all printers**<br>Leverage varies by printer type; implementation can be inexpensive (e.g. improving software algorithms) or expensive (e.g. improving hardware capabilities). | **1. Avoiding failed prints**<br>Leverage varies by application; already strongly incentivised by existing market forces.<br><br>**2. Hollowing parts for extrusion printers**<br>Leverage varies by application; already strongly incentivised by existing market forces. |
| IP | **1. Rights for third parties to print replacement parts for products (paying reasonable royalties as needed)**<br>Unclear leverage, but requires only simple legal action with precedent in other industries. No technology development required. | | |

# Green 3DP Scorecard?



# Priorities for Sustainability in 3D Printing



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# Manufacturing Usually Dwarfs Transport