Creating a *Sustainable Materials Management* (SMM) Model for Consumer Technology

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A collaboration among:
Golisano Institute for Sustainability at Rochester Institute of Technology
Consumer Technology Association
Staples Sustainable Innovation Lab

R·I·T

Golisano Institute for Sustainability

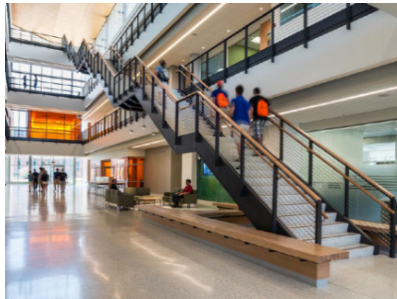# Golisano Institute for Sustainability

Academic Programs

- Sustainability Ph.D.
- Sustainable Systems M.S.
- M. Architecture

Research & development

- Industrial ecology and life cycle assessment
- Sustainable mobility and energy systems
- Food waste valorization
- Critical materials and recycling
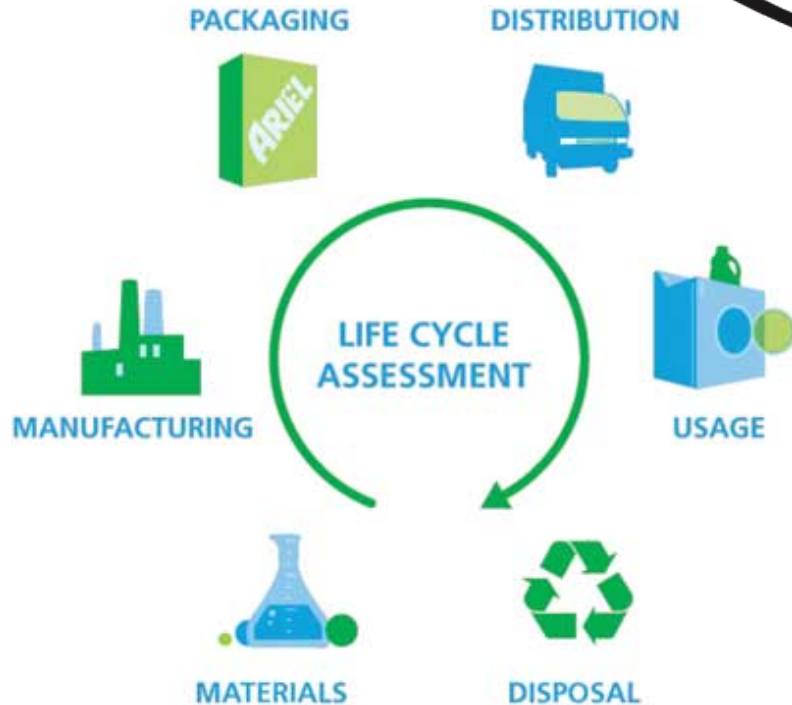- Sustainable supply chains

Campus sustainability

Community and global engagement

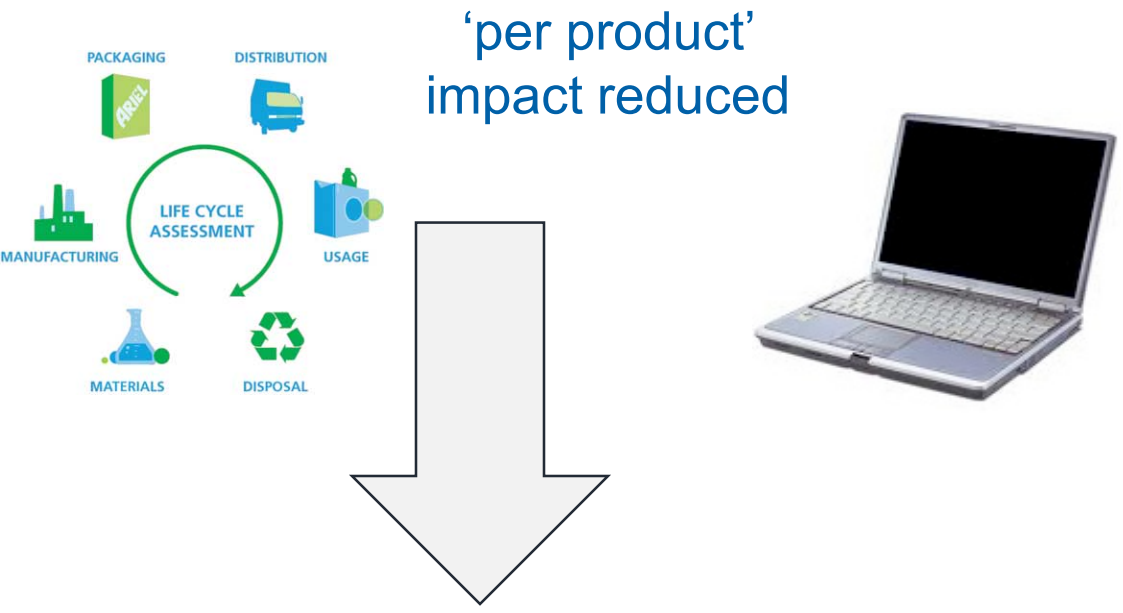# Background: Consumer electronics have a complex life cycle

Manufacturing

Transport

Resource Extraction

Distribution

Recycling

Use

Waste Management
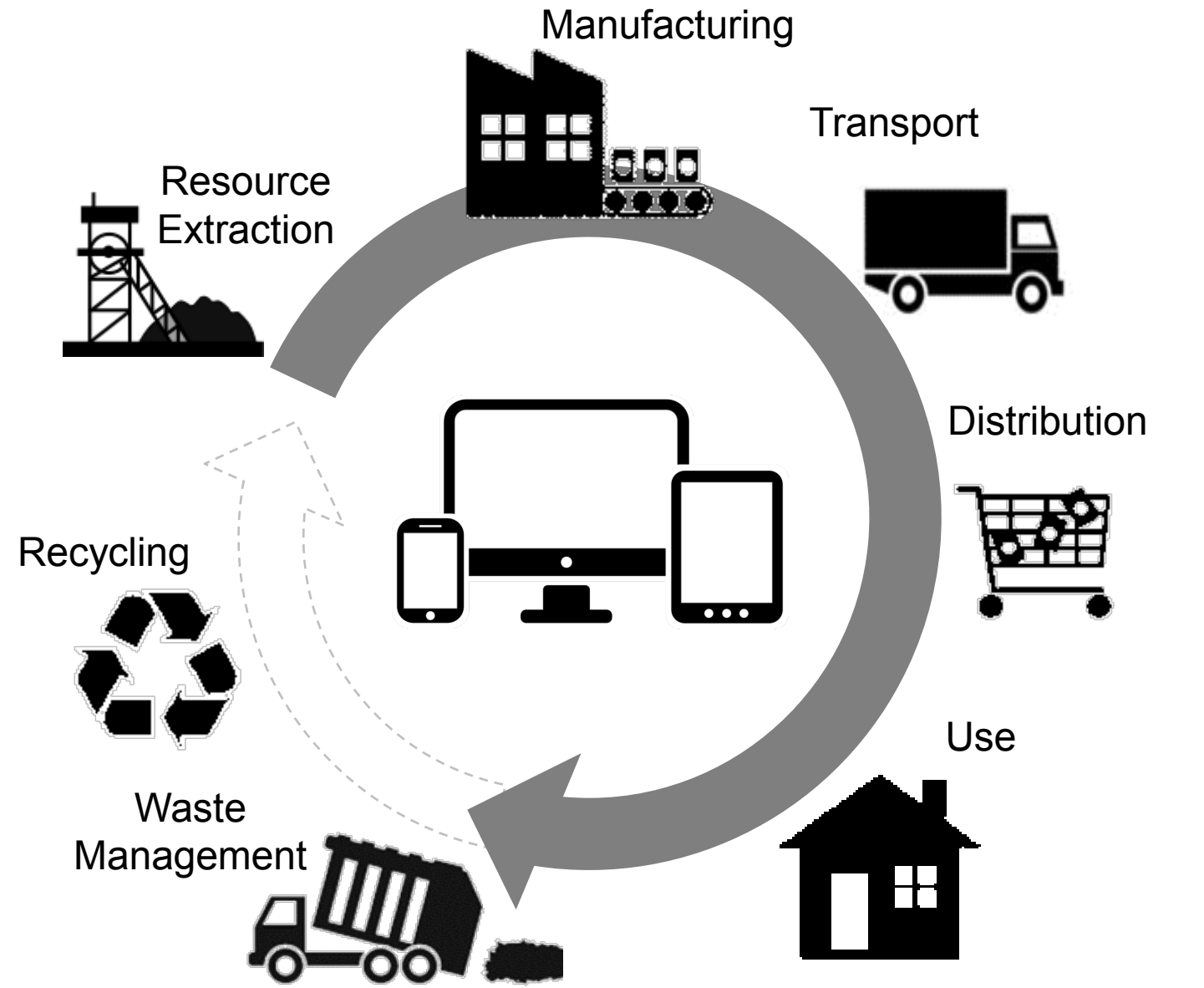
Traditional solution space

Traditional solution space

'per product'
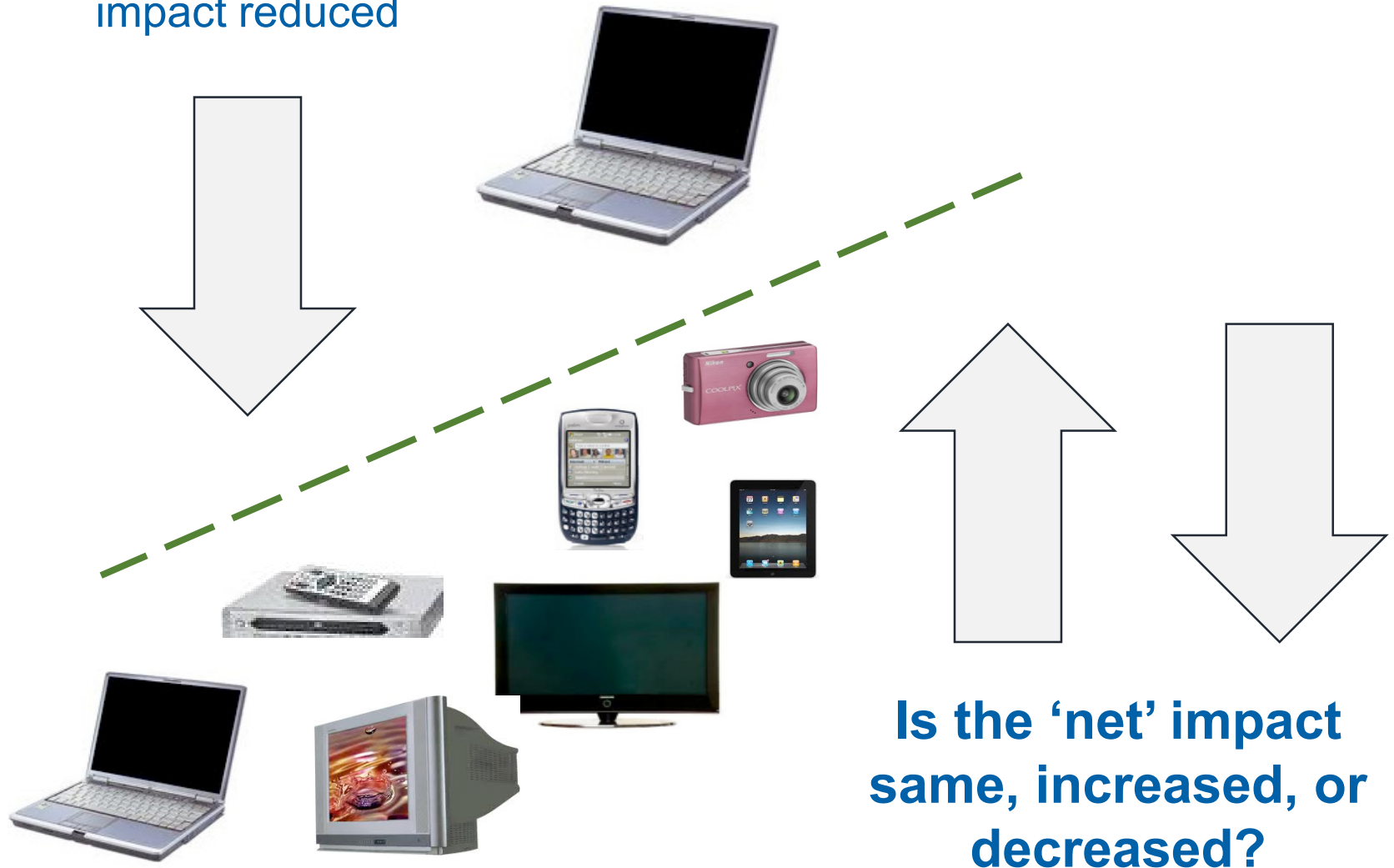impact reduced

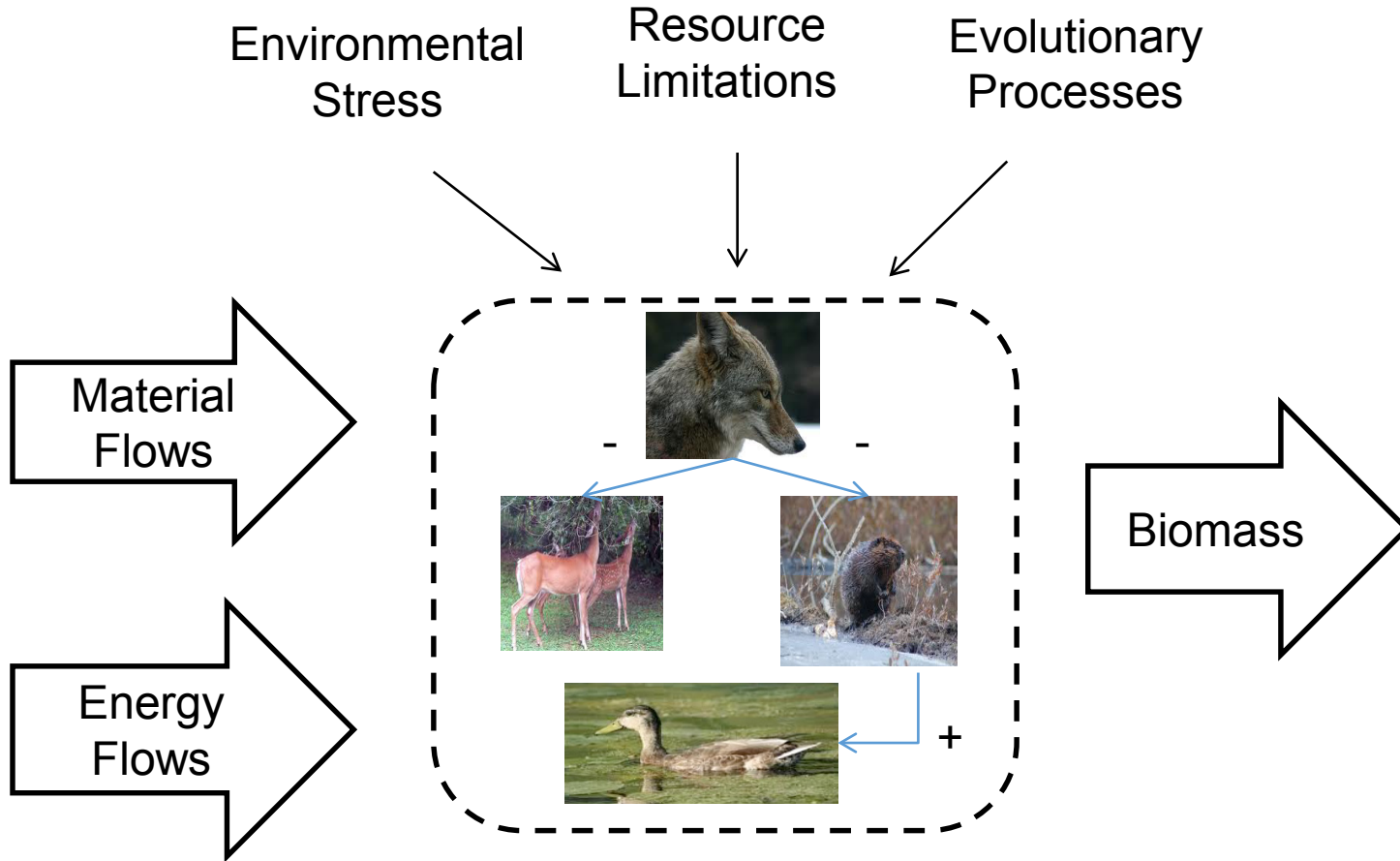# Intersection between these solutions and realistic patterns of consumption

'per product'
impact reduced

Is the 'net' impact
same, increased, or
decreased?

Parallel in ecological systems?
A biological ecosystem:

Environmental Stress

Resource Limitations

Evolutionary Processes

Material Flows

Energy Flows

Biomass

-

-

+

Consumer product ecosystem:
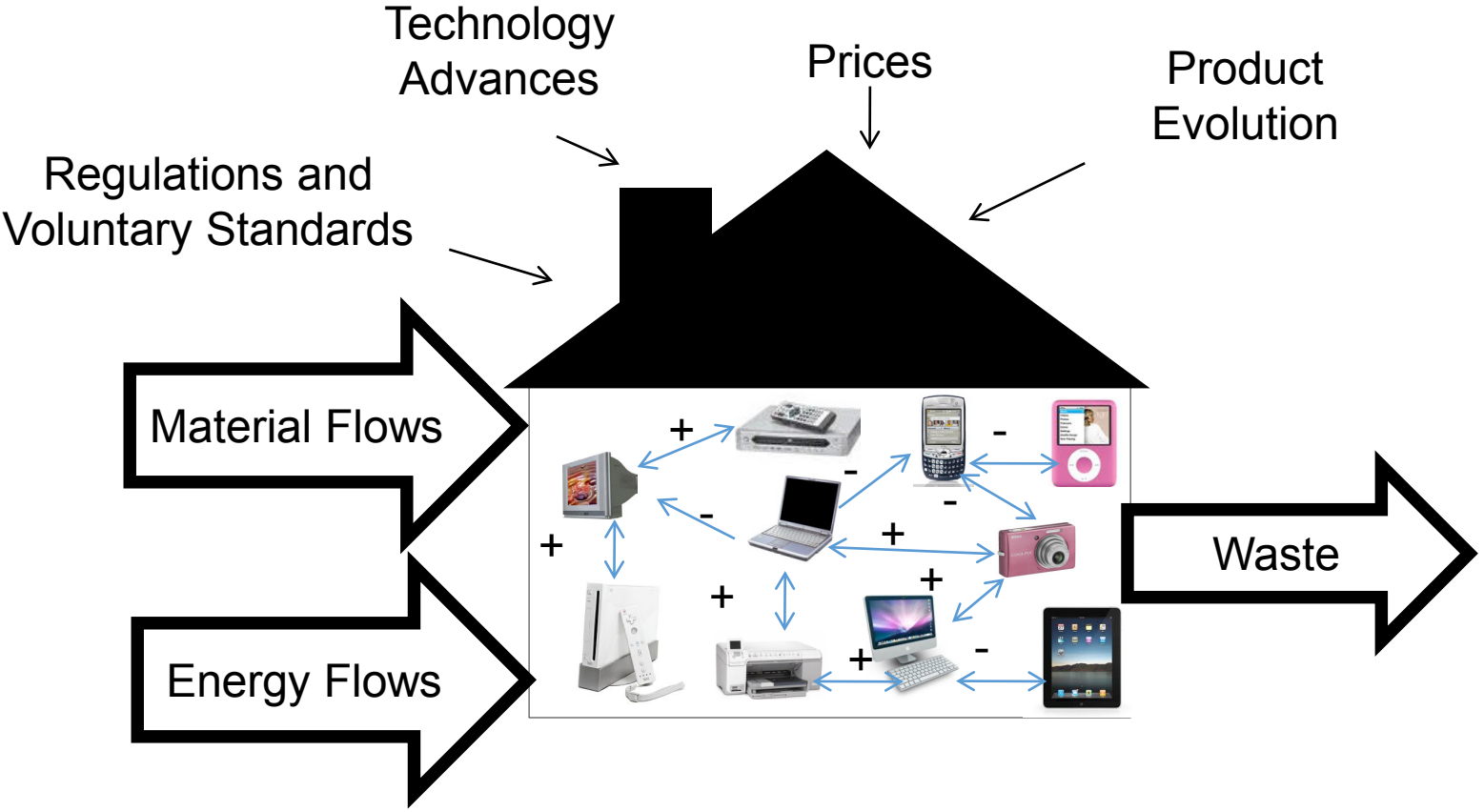
Research aims

- Create a SMM model that can quantify the net "material footprint" of the consumer technology ecosystem
  - Resources consumed
  - Products held in households
  - E-waste flows

- Apply data-driven analysis to establish a baseline for conventional technology products ("Phase 1")

- Understand key material trends over time

- Adapt and apply SMM model for proactive analysis of emerging trends, future products, and other life cycle environmental metrics ("Phase 2" – future work)

Approach:

Approach:
1) Characterize the technology product ecosystem

Inputs   Outputs

'Average' U.S. Household

Product adoption and ownership rates (CTA surveys)

Scope: "Average" U.S. Household, 21 most common products, 1990-2015

Approach:
2) Quantify unit inflows of new products

Product inflows - unit sales and shipments (CTA, IDC data)

'Average' U.S. Household Technology Ecosystem

Product adoption and ownership rates

Approach:
3) Quantify units held in stock and unit outflows

Inputs | Outputs

Product inflows - unit sales and shipments

'Average' U.S. Household Technology Ecosystem

Product adoption and ownership rates

Household Stock Changes

Product unit outflows*

Calculation: Δ Stock $= \Sigma$ inflows $- \Sigma$ outflows

*Outflows may be products for reuse or e-scrap

Approach:
4) Quantify mass and material flows

- Product disassembly and material characterization
- Data from literature and technical or policy documentation (NCER)
- Ongoing efforts to expand, analyze uncertainty, and catalog for public use
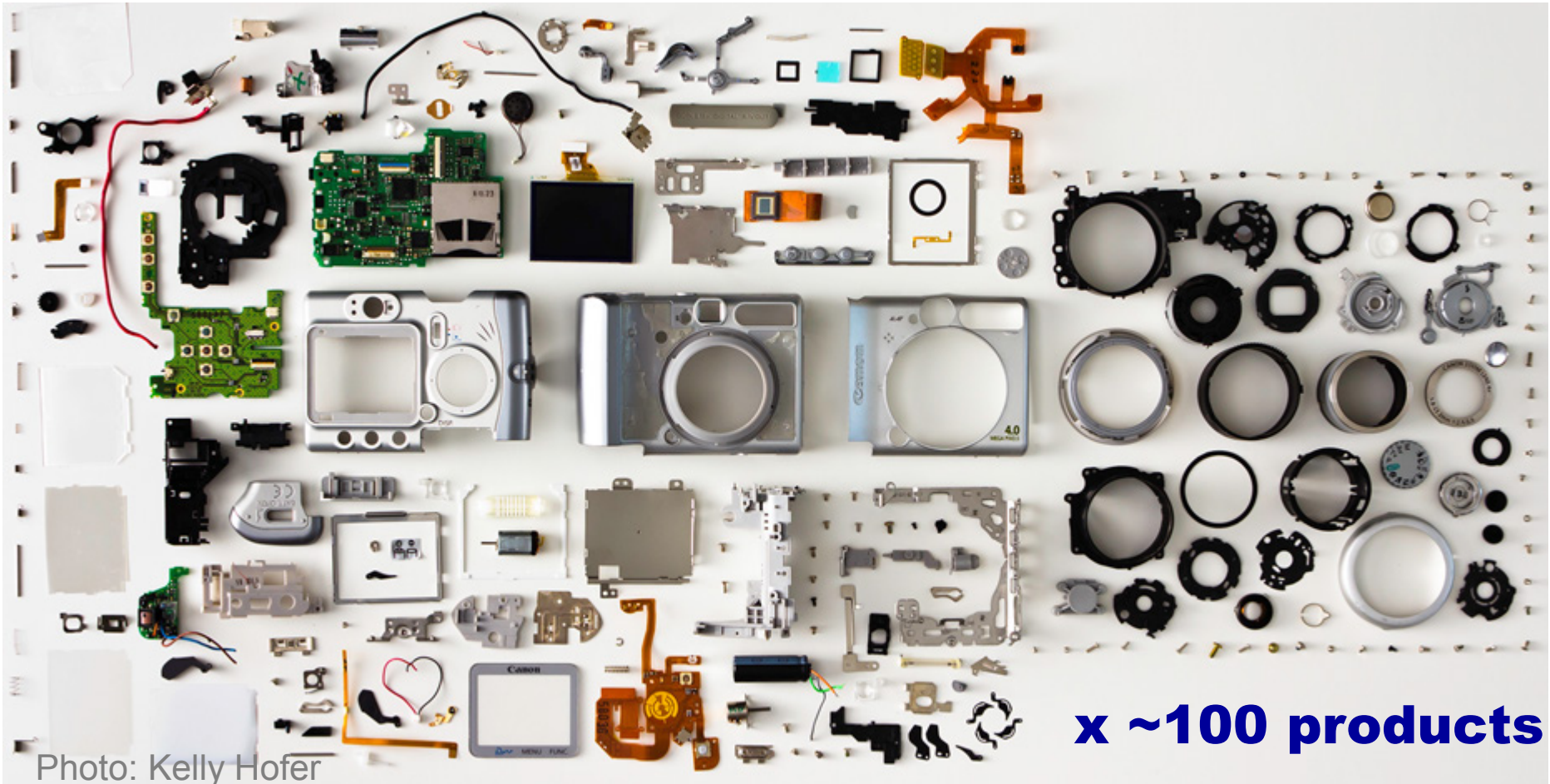
Photo: Kelly Hofer

x ~100 products

Approach:
4) Quantify mass and material flows, cont.

Inputs Outputs

Product inflows - unit sales and shipments

'Average' U.S. Household Technology Ecosystem

Product adoption and ownership rates

Average product mass, bill of materials

Household Stock Changes

Product unit outflows

Cumulative mass and material consumed, in stock, and in outflows
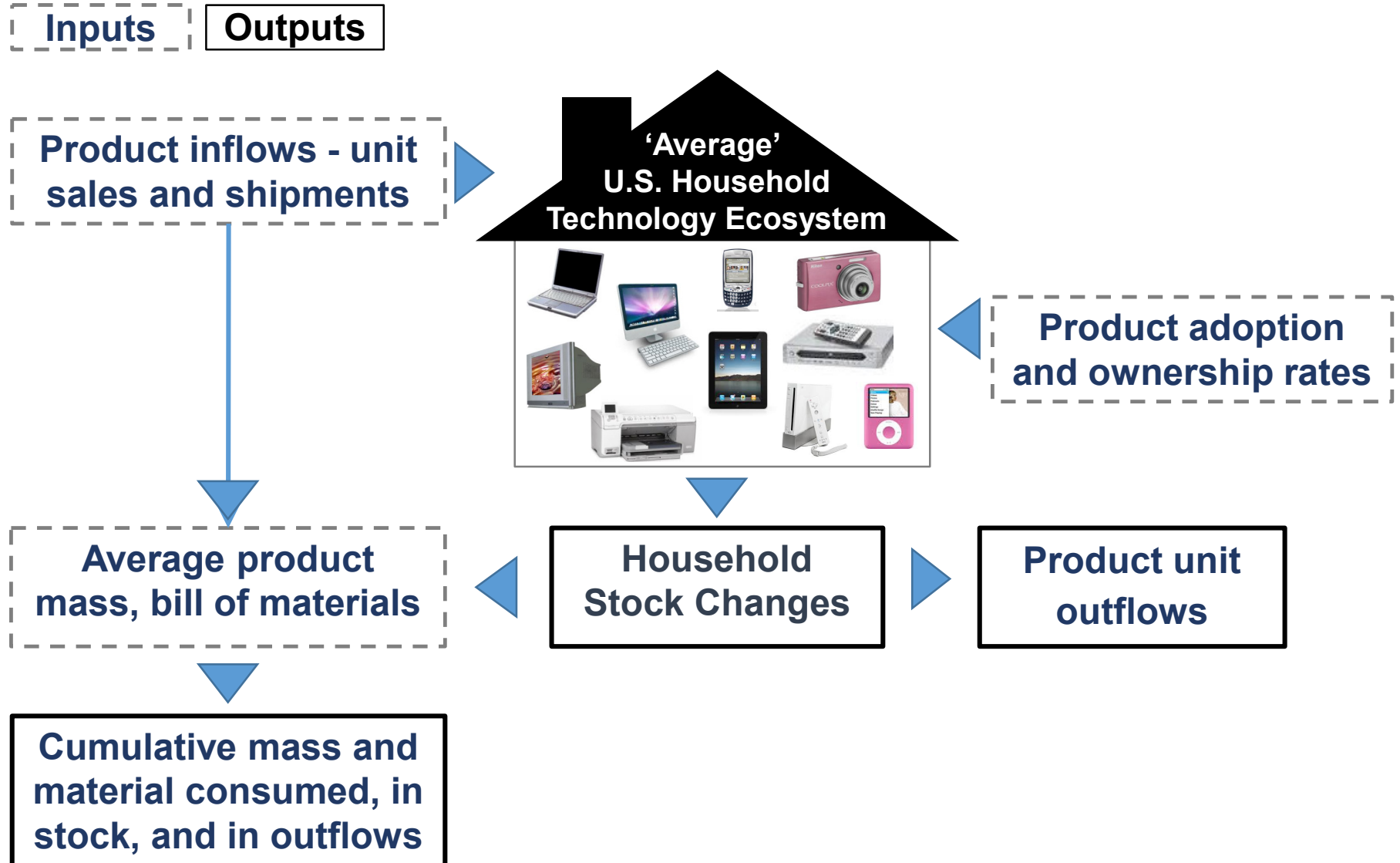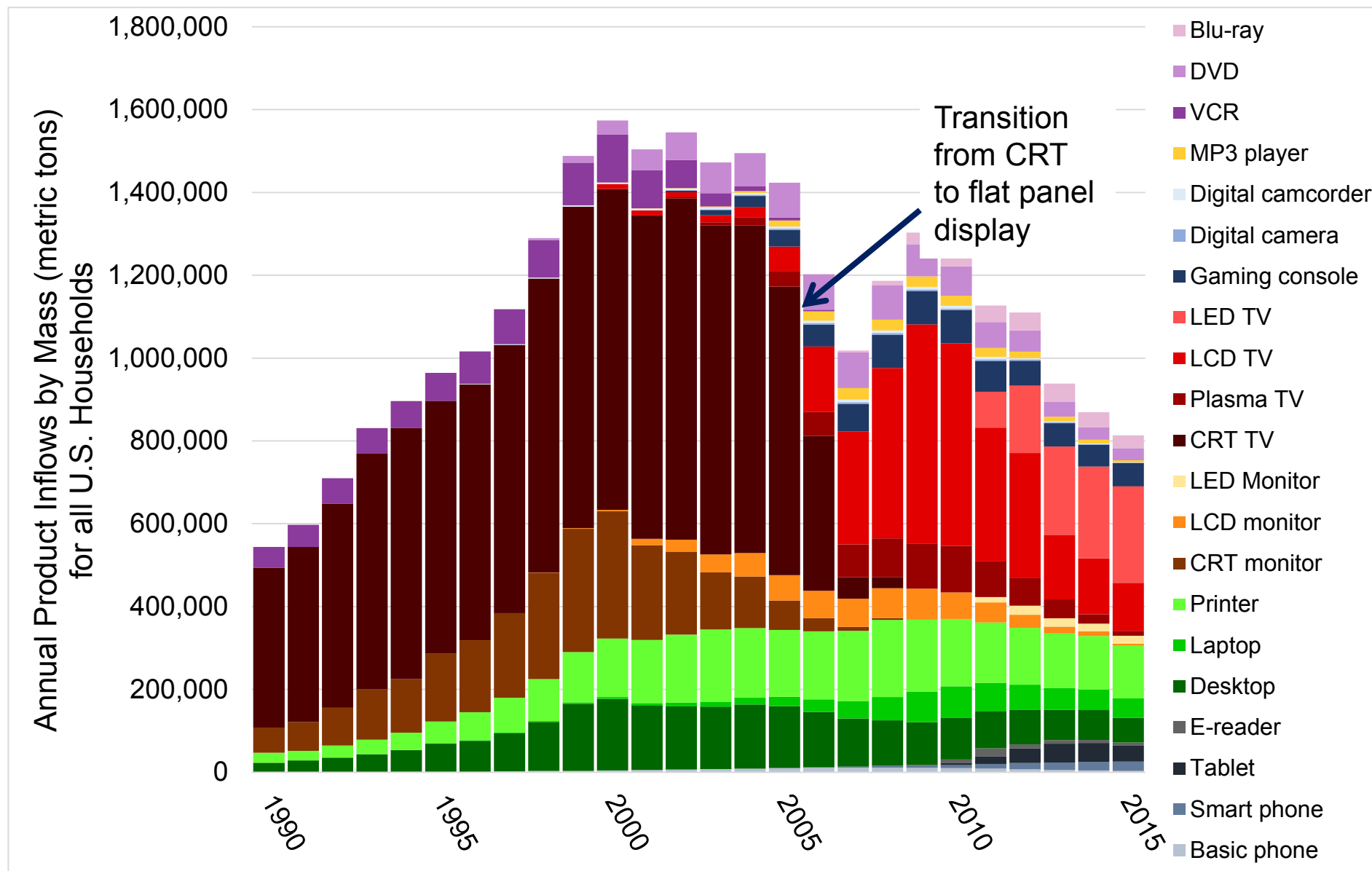
Key findings

1. Product consumption is growing, but net material footprint is beginning to slow
   - Consumer demand
   - Technological progress and product substitution

Sales of new technologies into U.S. Households

Huge growth in mobile device consumption, with recent shifts toward device convergence

Legend (top to bottom):
- Blu-ray
- DVD
- VCR
- MP3 player
- Digital camcorder
- Digital camera
- Gaming console
- LED TV
- LCD TV
- Plasma TV
- CRT TV
- LED Monitor
- LCD monitor
- CRT monitor
- Printer
- Laptop
- Desktop
- E-reader
- Tablet
- Smart phone
- Basic phone

Y-axis: Annual Product Inflows in units for all U.S. Households

Y-axis values: 0, 50,000,000, 100,000,000, 150,000,000, 200,000,000, 250,000,000, 300,000,000, 350,000,000, 400,000,000, 450,000,000, 500,000,000

X-axis: 1990, 1995, 2000, 2005, 2010, 2015

Net weight of products consumed

Chart: Net weight of products consumed. Vertical axis: Annual Product Inflows by Mass (metric tons) for all U.S. Households, ranging from 0 to 1,800,000. Horizontal axis: years from 1990 to 2015.

Annotation: Transition from CRT to flat panel display

Legend: Blu-ray, DVD, VCR, MP3 player, Digital camcorder, Digital camera, Gaming console, LED TV, LCD TV, Plasma TV, CRT TV, LED Monitor, LCD monitor, CRT monitor, Printer, Laptop, Desktop, E-reader, Tablet, Smart phone, Basic phone

Key findings

1. Product consumption is growing, but net material footprint is declining
   - Consumer demand
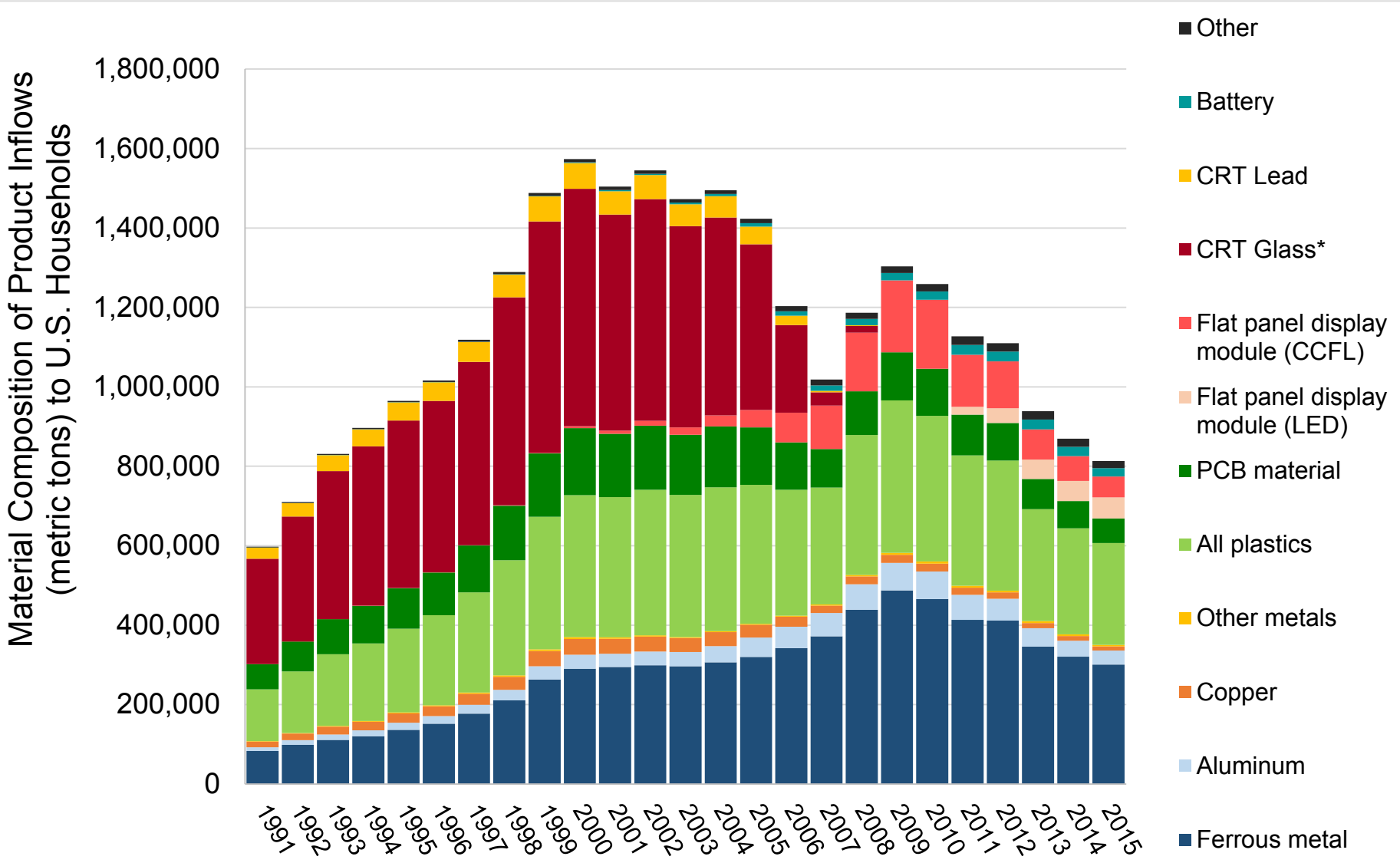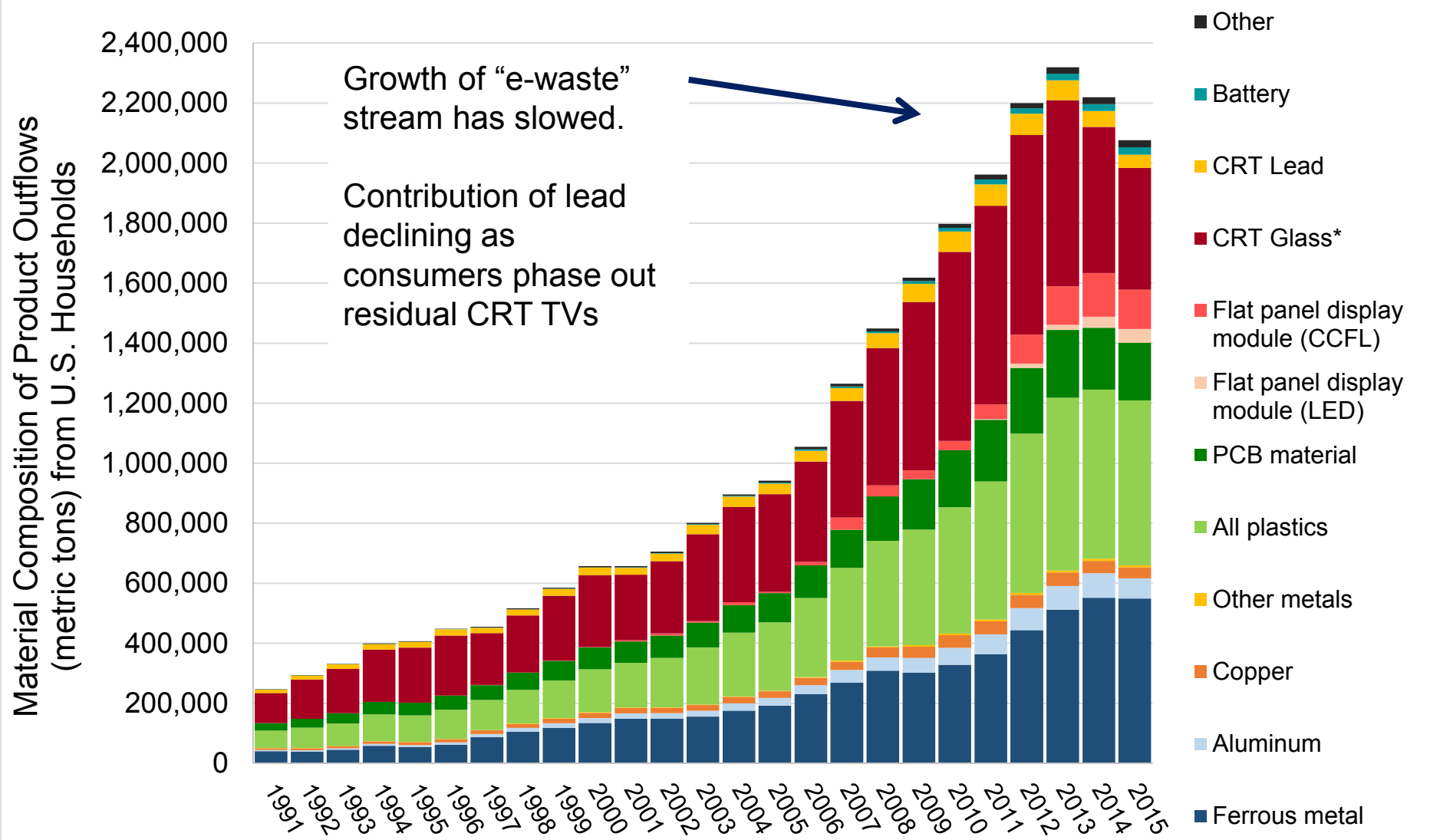   - Technological progress and product substitution

2. Materials of concern have declined, although overall material profile fairly steady
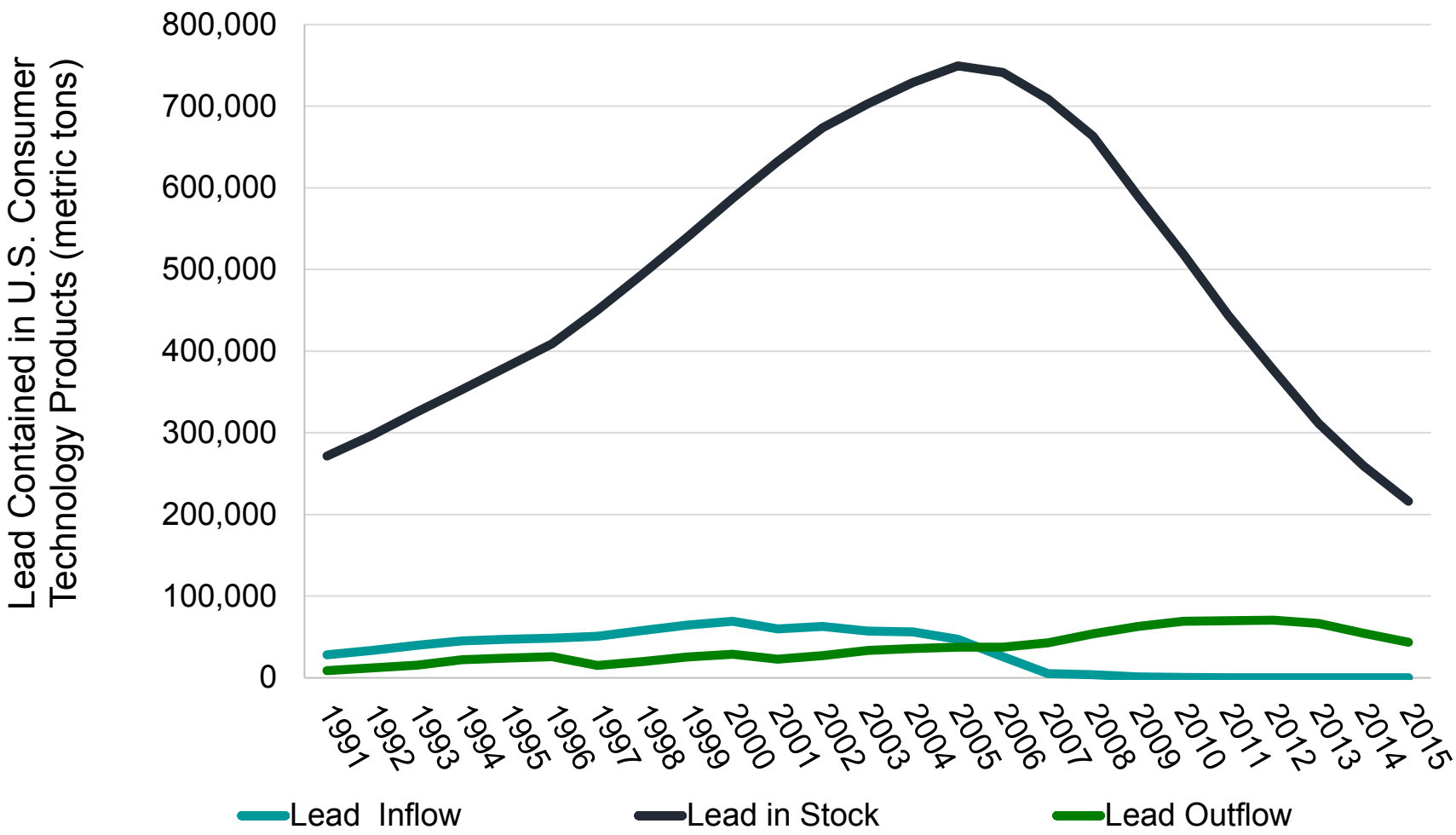   - Technological progress and product substitution
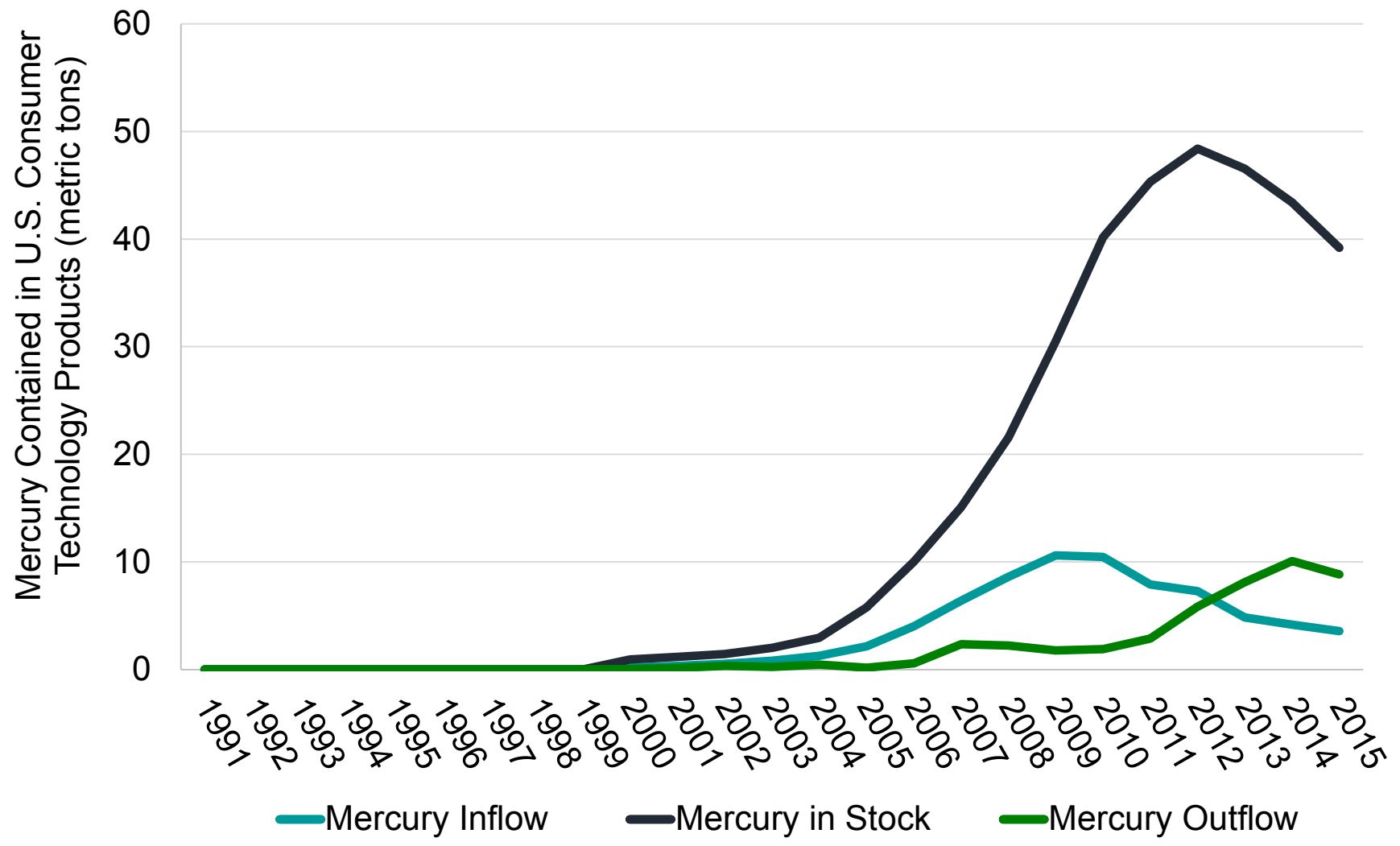
Breakdown of major materials consumed

Breakdown of materials entering the waste stream

Growth of "e-waste" stream has slowed.

Contribution of lead declining as consumers phase out residual CRT TVs

Decline in lead (in CRT and circuit boards)

Decline in mercury (in CCFL LCD displays)

Mercury Contained in U.S. Consumer Technology Products (metric tons)

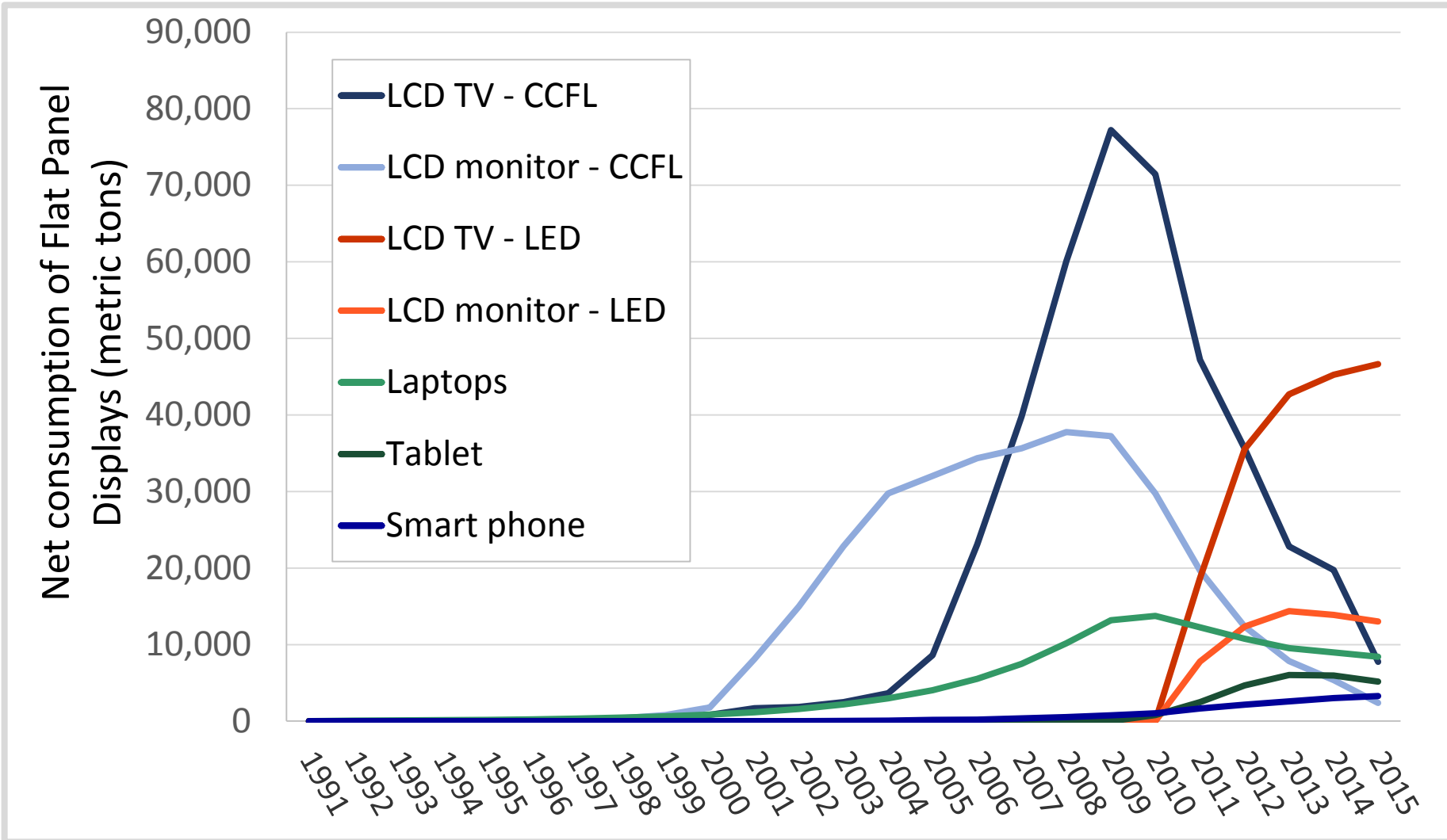— Mercury Inflow   — Mercury in Stock   — Mercury Outflow
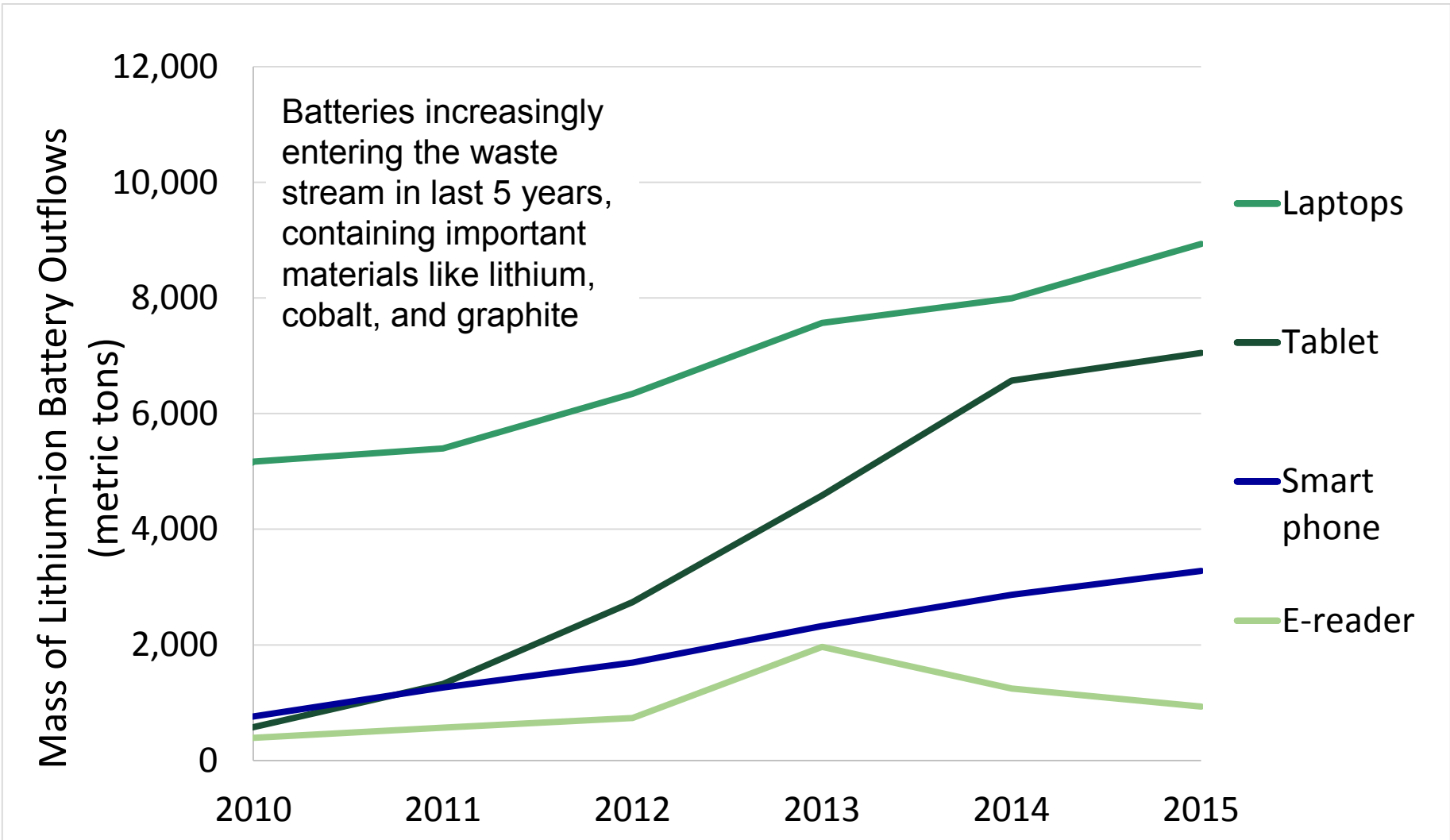
Key findings

1. Product consumption is growing, but net material footprint is declining
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2. Materials of concern have declined, although overall material profile fairly steady
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3. Opportunities for new innovations
   - Scarce materials and the circular economy
   - Emerging recycling issues

Material consumption in flat panel technology

Opportunities for closing the loop on critical materials (e.g., indium) and rare earth elements:

Emerging lithium-ion battery waste stream

Mass of Lithium-ion Battery Outflows (metric tons)

Batteries increasingly entering the waste stream in last 5 years, containing important materials like lithium, cobalt, and graphite

- Laptops
- Tablet
- Smart phone
- E-reader

Next steps

- Phase 1 established a baseline material footprint

  - Currently editing a high-level summary report to disseminate via CTA

  - Planned to add and apply uncertainty analysis within the SMM model

  - Publication of an academic research article

Next steps

- Phase 2 will expand the SMM model with a forward-looking perspective

    - Focused on model development

    - Validation using case studies of emerging technologies and scenario analysis

    - Environmental metrics that based on life cycle thinking

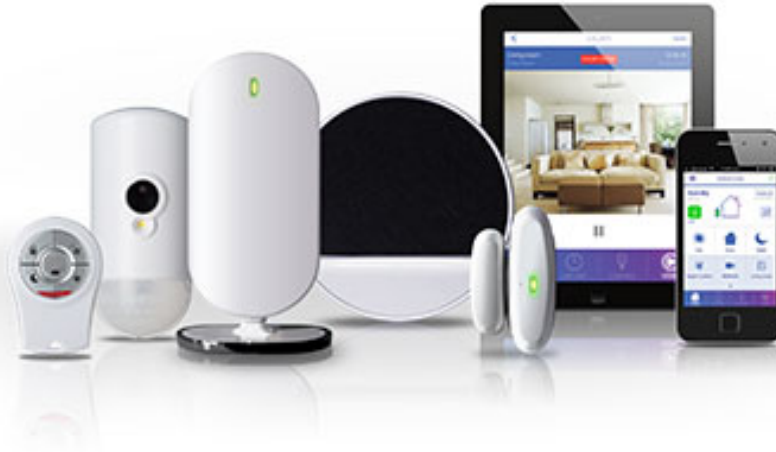   - Dissemination of modeling tools (Excel, Matlab)

Next steps

- Case studies in consideration

  - Discrete consumer technology products - traditional and new

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- ## Case studies in consideration

  - Discrete consumer technology products - traditional and new

  - Products using electricity that are now "smart"

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- ## Case studies in consideration

  - Discrete consumer technology products - traditional and new

  - Products using electricity that are now "smart"

  - Products with no historical technology function but electronics are added for smart functionality

Contact

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