Sustainable Material Management and 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
U.S. EPA

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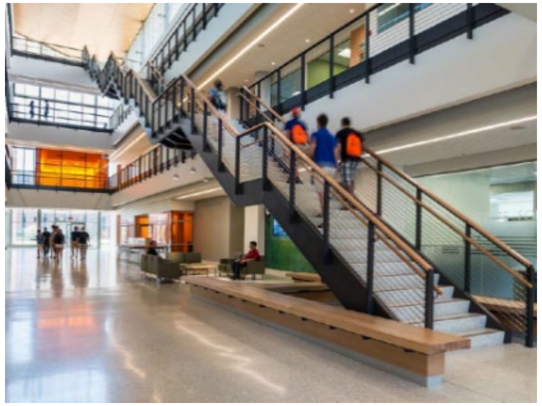
R·I·T

Golisano Institute for Sustainability

Golisano Institute for Sustainability

Focus on Sustainable Systems at RIT



Knowledge to enable the future sustainability workforce

- Graduate degrees
- Corporate training
- Focus on sustainable technology and infrastructure

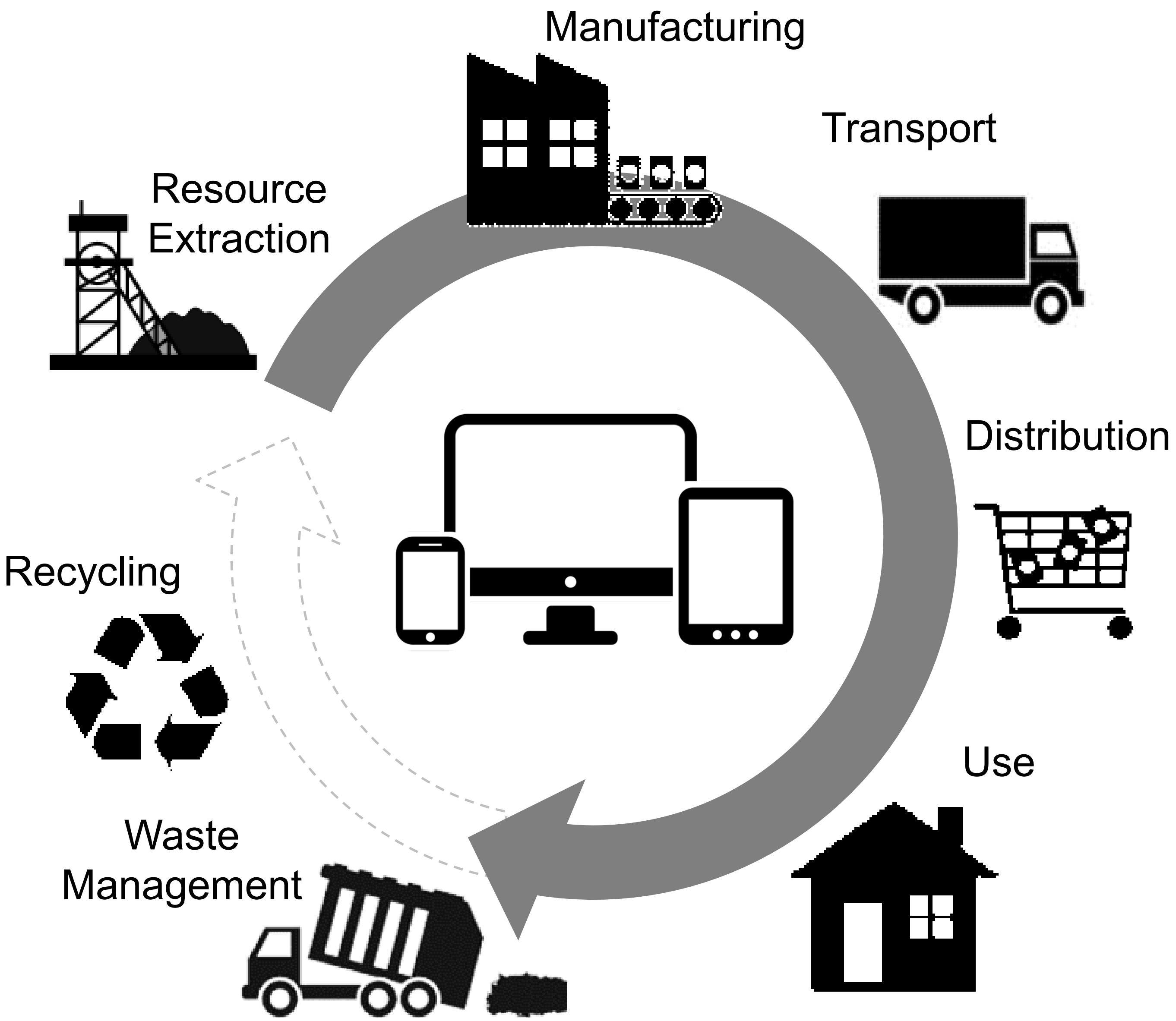
Research & development

- University-industry partnerships
- “Triple-bottom-line”: people, prosperity, and the planet

Solutions to global challenges

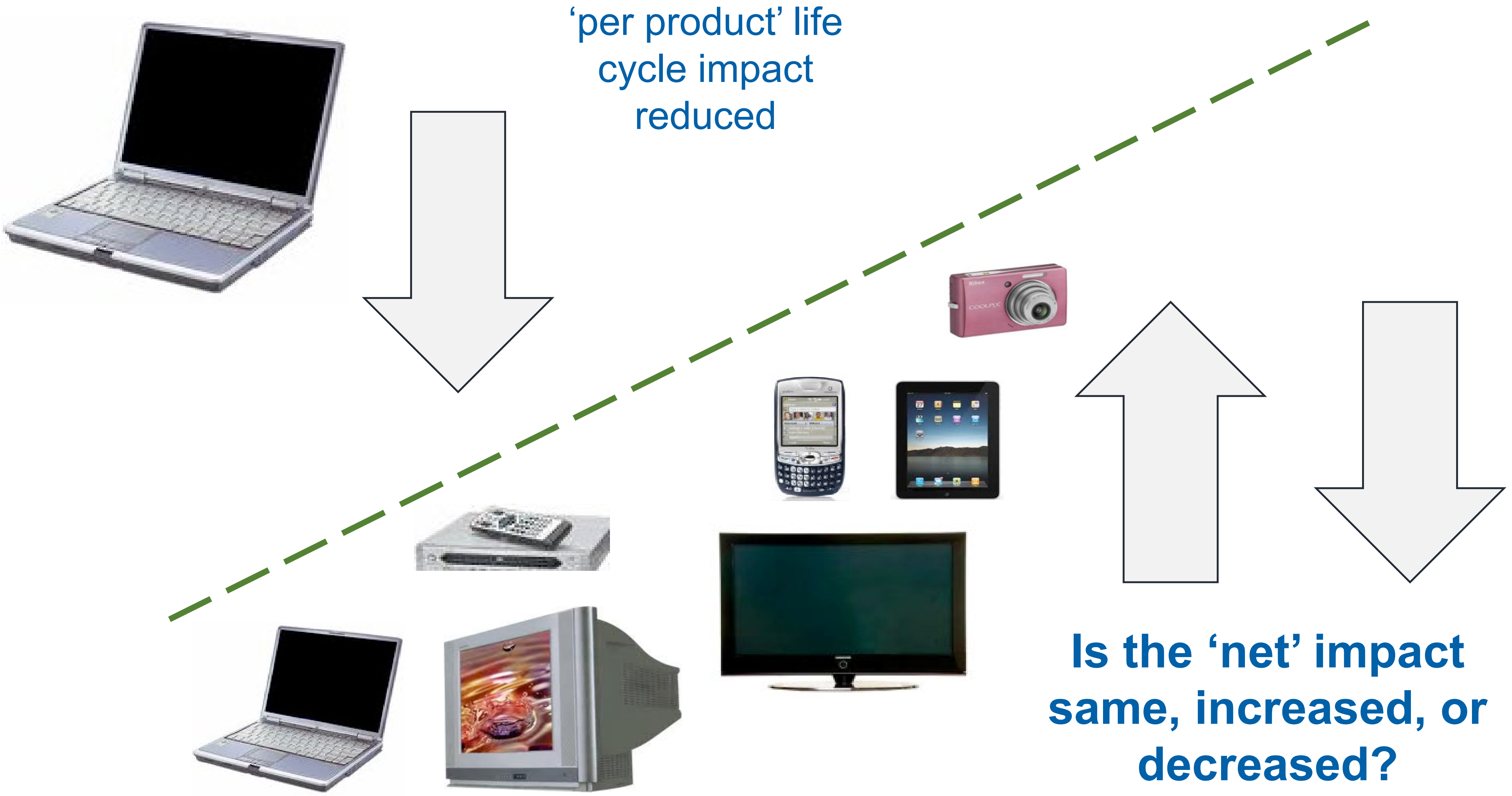
- Resource and energy security
- Food supply chains
- Sustainable mobility
- Eco-efficient manufacturing
- Waste minimization and management

Sustainability and electronics



Climate change
Water consumption
Material scarcity
Labor and equity
Human health
Economic cost
Pollution
Waste generation
Etc.…

Research goal 2: Assess sustainability at the intersection of technology and consumption



Research phases

1. Analyze the “material footprint” of historic + current consumer electronics adoption
   - ➢ Data-driven baseline
2. Forecast issues and opportunities expected for emerging consumer electronics adoption
   - ➢ Future-oriented predictive model

- Broad material categories
- Aggregate U.S. flows

3. Assess sustainability challenges of materials needed to enable future adoption trends
   - ➢ Sustainable materials management (SMM)

- Deep dive into specific materials
- Implications of material choice

Phase 1 and 2: Assess historic + predict future material footprint

Approach:
1) Quantify products purchased, stored, and discarded annually

Data

Results

Product consumption - unit sales and shipments

Product ownership rates

Change in unit stock (stored)

Estimated unit discards*

Scope: "Average" U.S. Household, 21 most common products, 1990-2018

*Discards may be products for reuse, recycling, or waste

Approach:
2) Determine average product mass and material composition

- 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

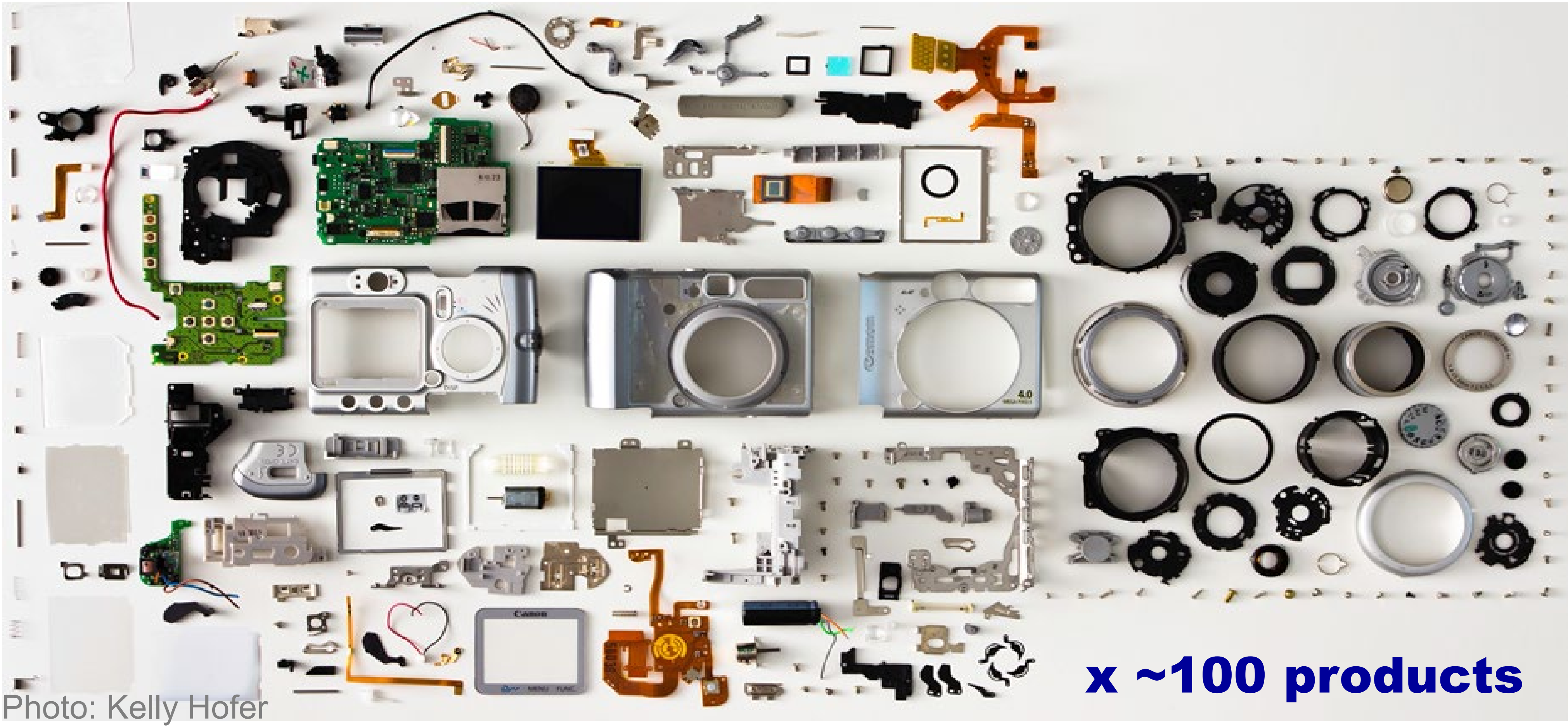


Photo: Kelly Hofer

Approach:
3) Determine trends in the electronics material footprint

Data

Results

Product consumption - unit sales and shipments

Product ownership rates

Change in unit stock (stored)

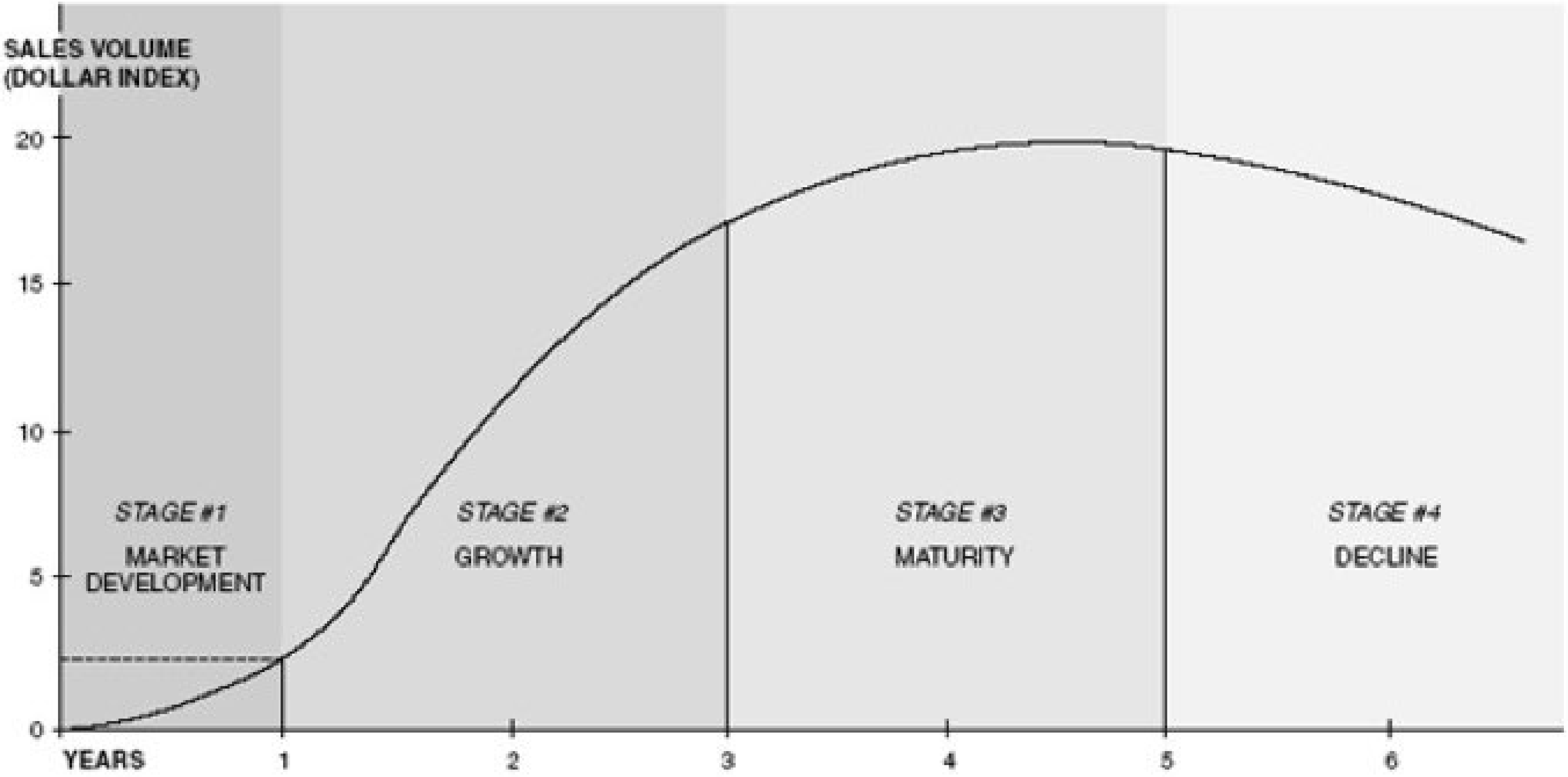
Estimated unit discards*

Average product mass, bill of materials

Material footprint

Approach:
4) Use past product adoption trends to predict future patterns

Products follow consistent pattern: “S-curve” growth, plateau, and decline on introduction of a competing technology



Levitt 1965

Key findings

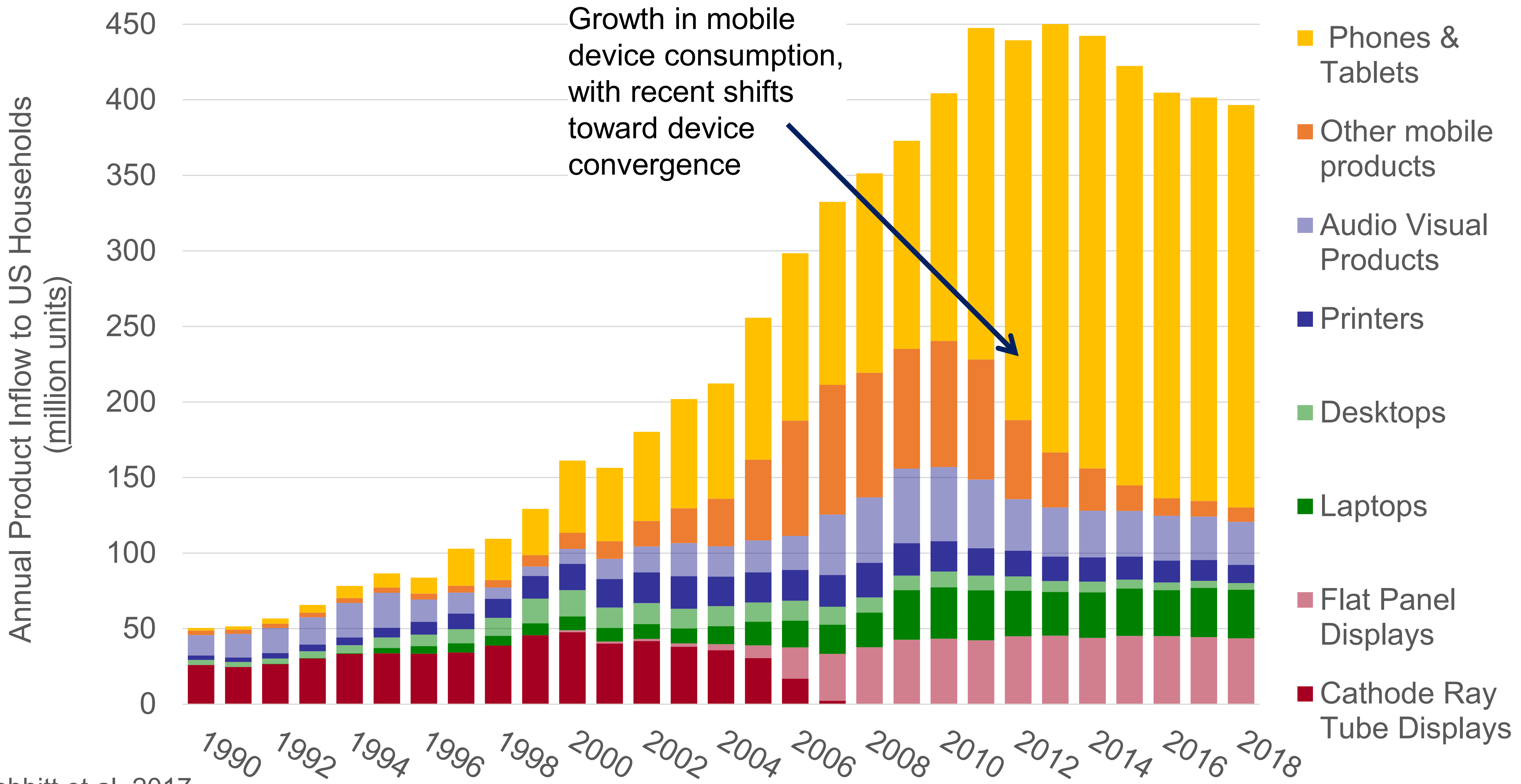
Citations:

Babbitt, C.W. Althaf, S., Chen, R. 2017. “Sustainable Materials Management for the Evolving Consumer Technology Ecosystem – Phase 1: Modeling Framework and Baseline Results.” A report to the Staples Sustainable Innovation Lab and the Consumer Technology Association.

Babbitt, C.W. Althaf, S., Chen, R. 2018. “Sustainable Materials Management for the Evolving Consumer Technology Ecosystem – Phase 2: Predictive Modeling of Emerging Technology Products.” A report to the Staples Sustainable Innovation Lab and the Consumer Technology Association.

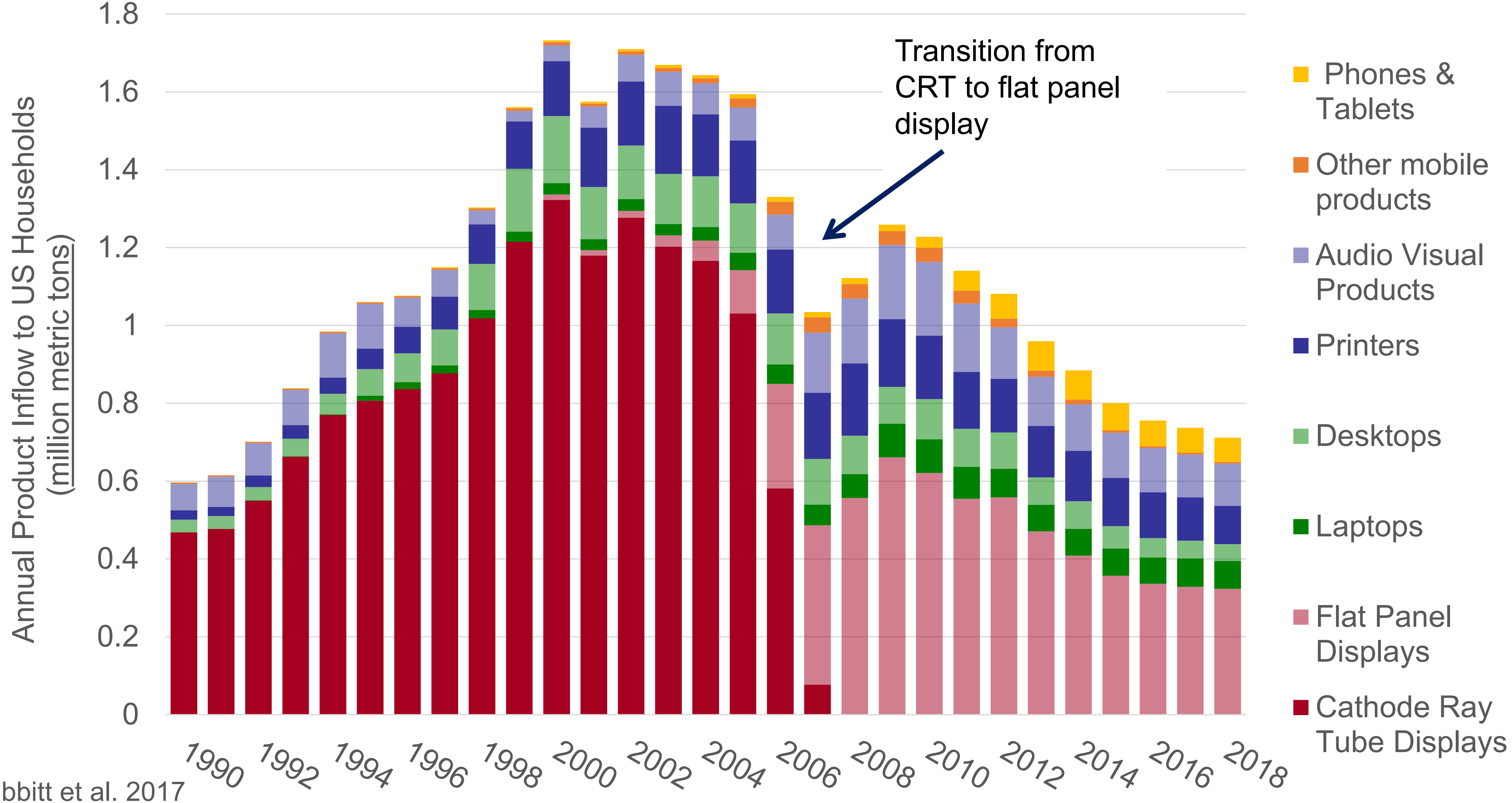
Althaf, S., Babbitt, C. W., & Chen, R. 2019. “Forecasting electronic waste flows for effective circular economy planning”. *Resources, Conservation and Recycling*, 151, 104362.

Unit product consumption has grown and evolved



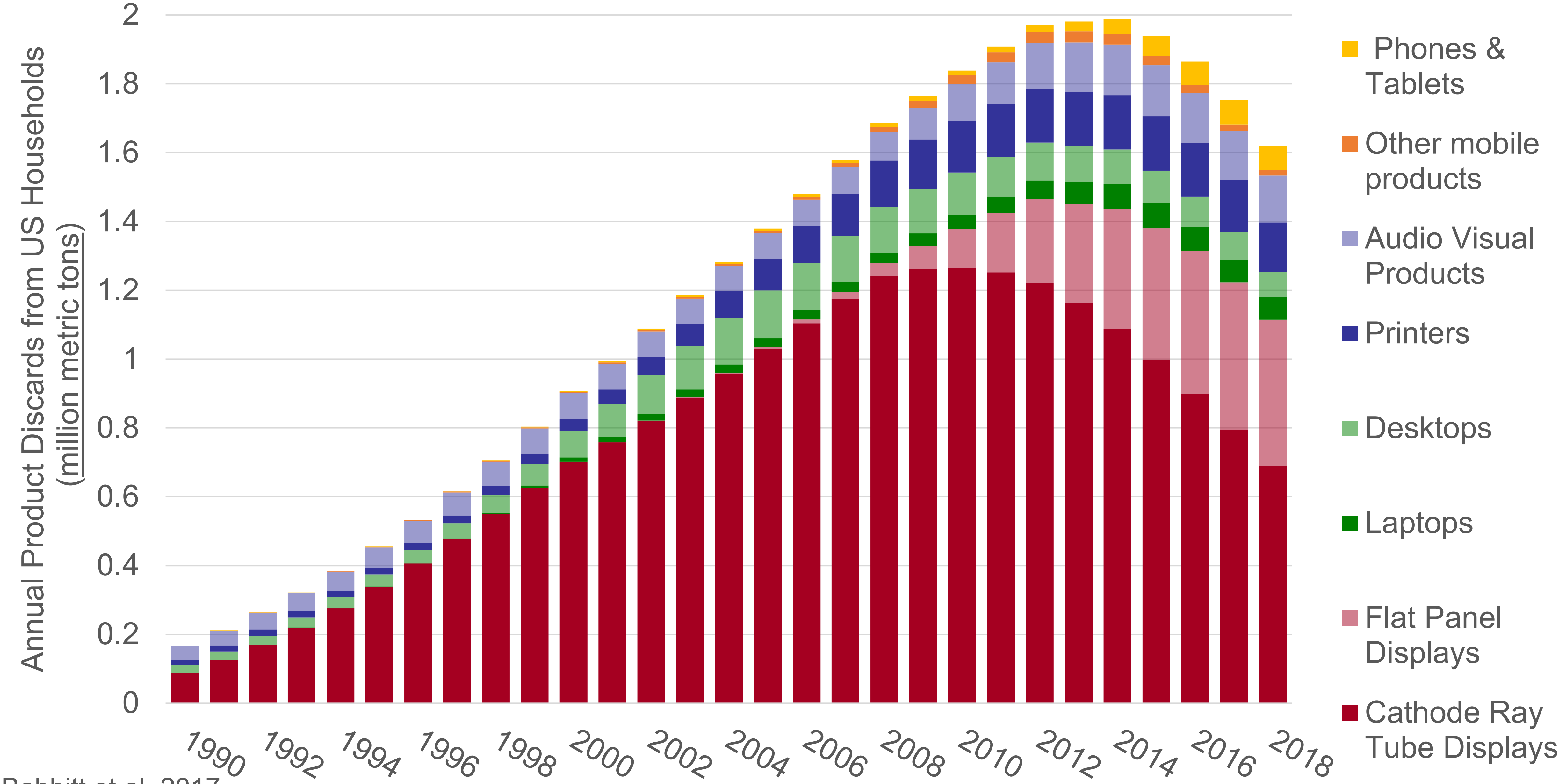
Babbitt et al. 2017

Material intensity of consumption has declined



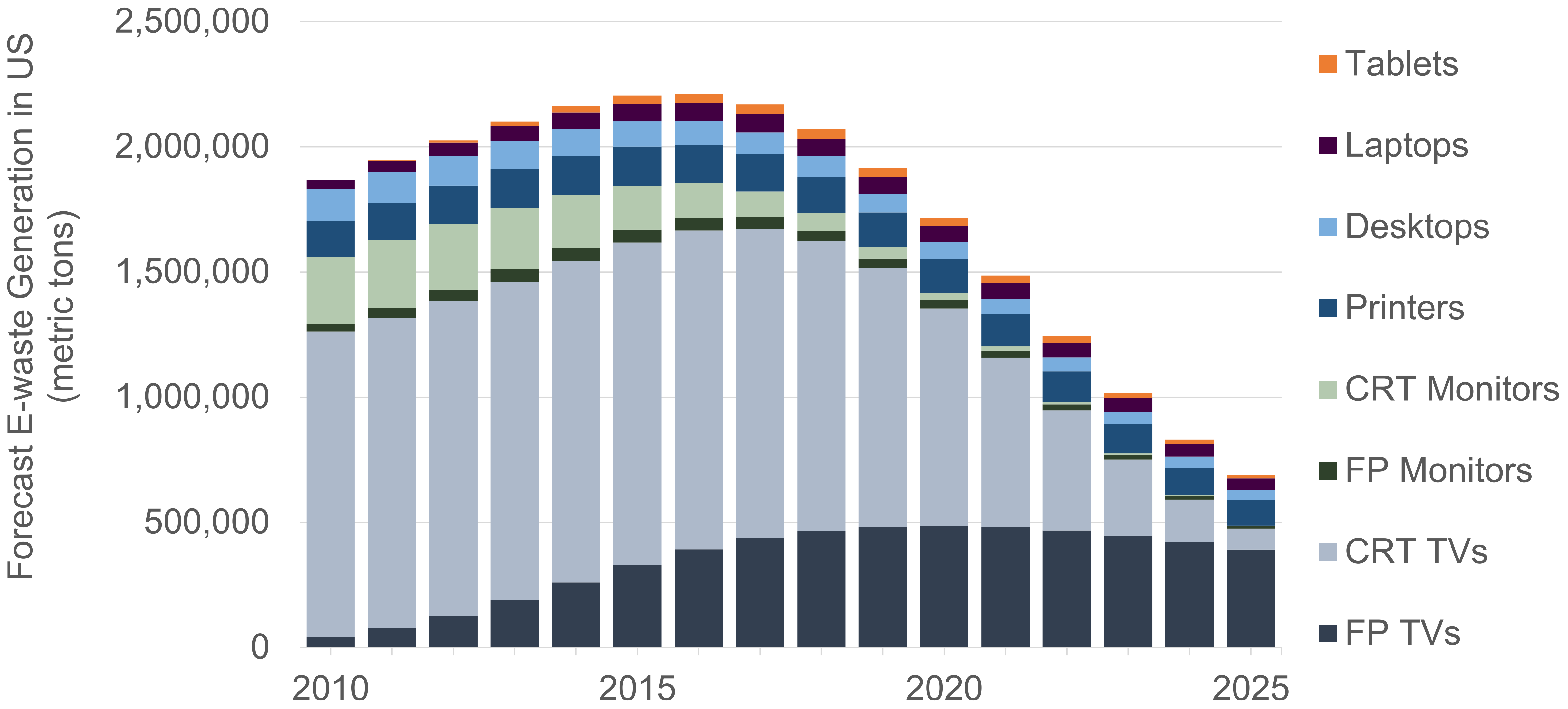
Babbitt et al. 2017

Mass of consumer e-waste has begun a comparable decline



Babbitt et al. 2017

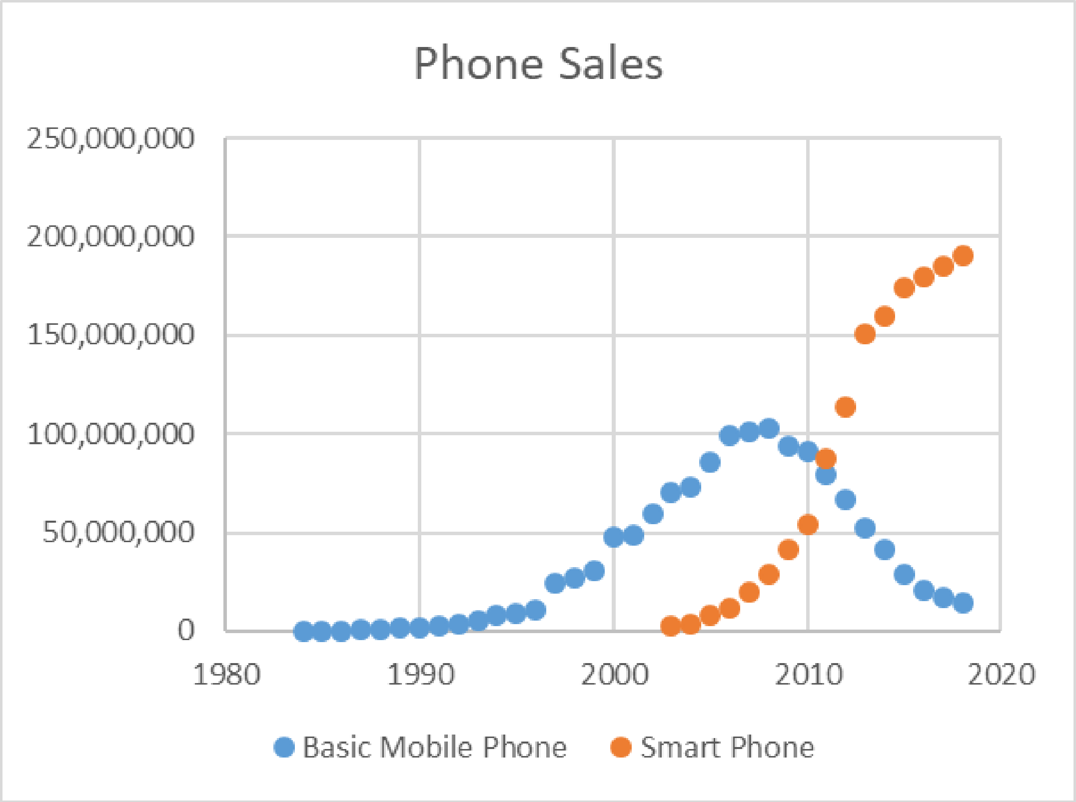
Regulated* e-waste forecasted to continue a decline

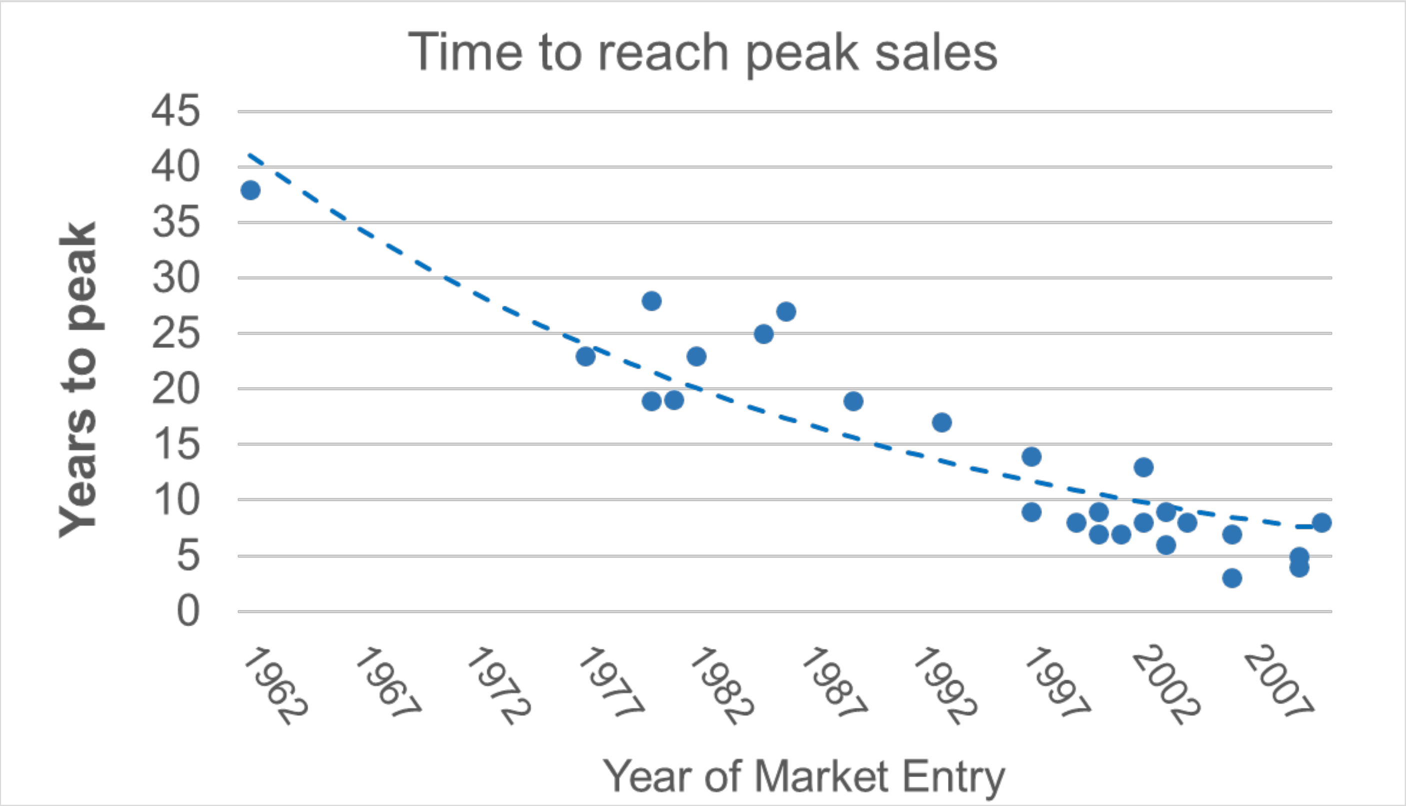


Althaf et al. 2019

CRT: Cathode Ray Tube FP: Flat Panel

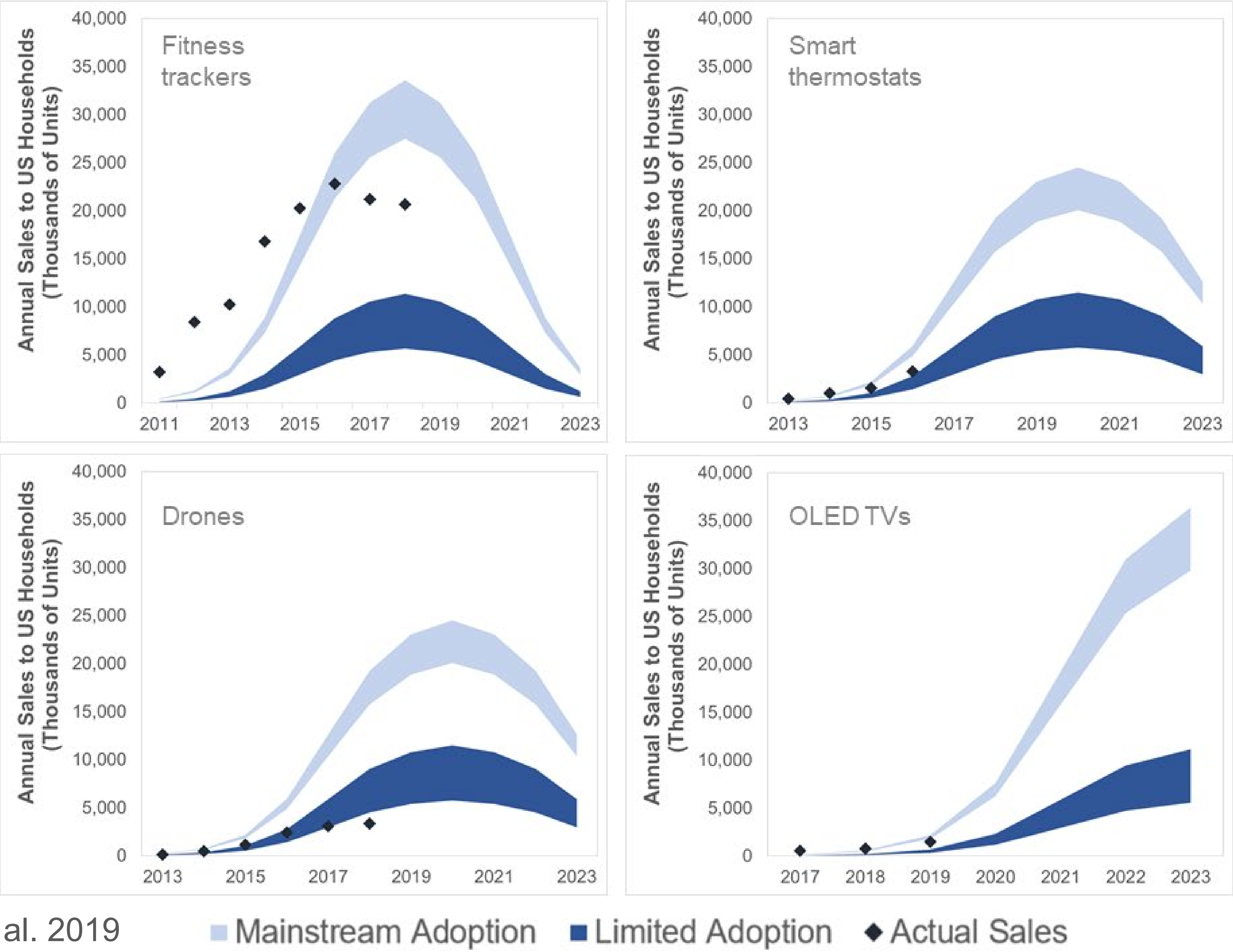
New product adoption follows consistent trends, but over shrinking innovation cycles





Babbitt et al. 2018

Emerging products quickly peak, minimal waste contribution anticipated for mobile devices



Althaf et al. 2019

Other materials management challenges are expected

Rubber, Components glued

Indium, Cobalt, Lithium, Gold

Babbitt et al. 2018

photo credit: Alex Tong

Goal 3: Evaluate sustainable materials management

How can we proactively assess material risks and opportunities?

How can we communicate findings to support decision making?

Approach:

Create and apply SMM metrics to key materials*

Focus on ***common materials*** in electronics

- *Precious metals*
- *Base Metals*
- *Strategic / critical metals*
- *REEs (Rare Earth Elements)*
- *Hazardous materials*
- *Plastics*

Identify key **metrics** to capture sustainability risks across material life cycle

- *Economic*
- *Environmental*
- *Social*

Data Collection

- *Scientific articles*
- *Reports*
- *Government websites*

Analyze metrics data to identify key material hotspots

Based on

- *Risk level in metrics*
- *Use in electronics*
- *Relevance to U.S. economy*

Explore the potential sustainability solutions

- *Recycling*
- *Material substitution*
- *Supply chain diversification*

Metrics to proactively identify risks and opportunities

Lifecycle stages	Sustainability Concerns	SMM Metrics
Availability of materials	*How much is available?* *Where is it available?* *Are they scarce?* *How much is used in electronics?* *Demand in other sectors?*	Mineral reserve, Ore concentration Annual Mine Production Geographical concentration of production Electronics Sector Consumption Depletion rate

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Extracting and refining materials	*Environmental impacts of production* *Economic Impacts* *Social Impacts*	Carbon Footprint, Mineral Resource Demand, Energy Demand, Water Footprint Price (and price volatility) Socio-Political Stability of Producer Countries

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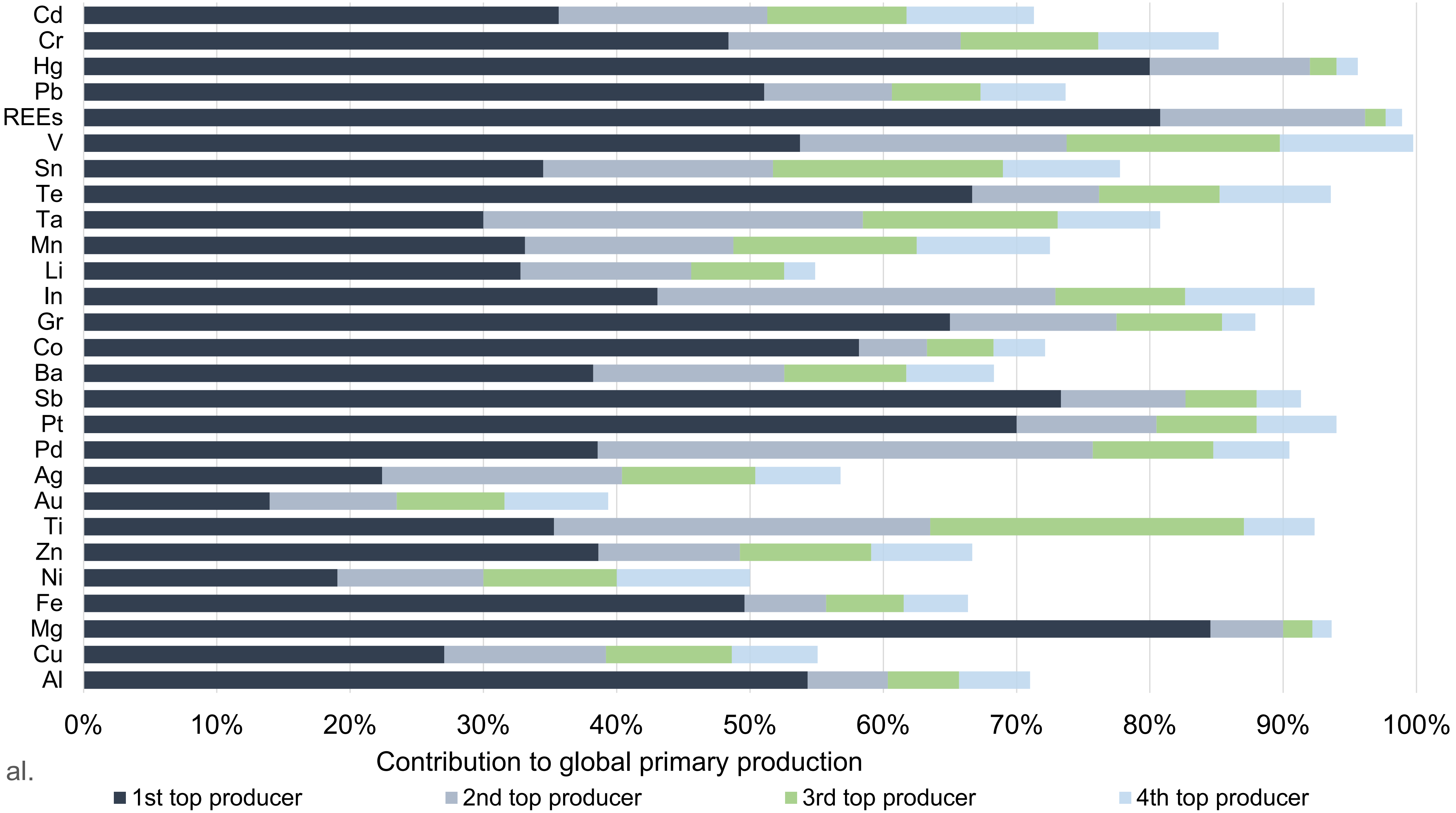
End-of-life material management	*How much is available to recycle?* *How much is recycled?* *What are the potential issues in recycling?*	Market for recycled material Dilution of material in waste, Potential for material circularity Performance of recycling processes Toxicity of materials if released

Key findings

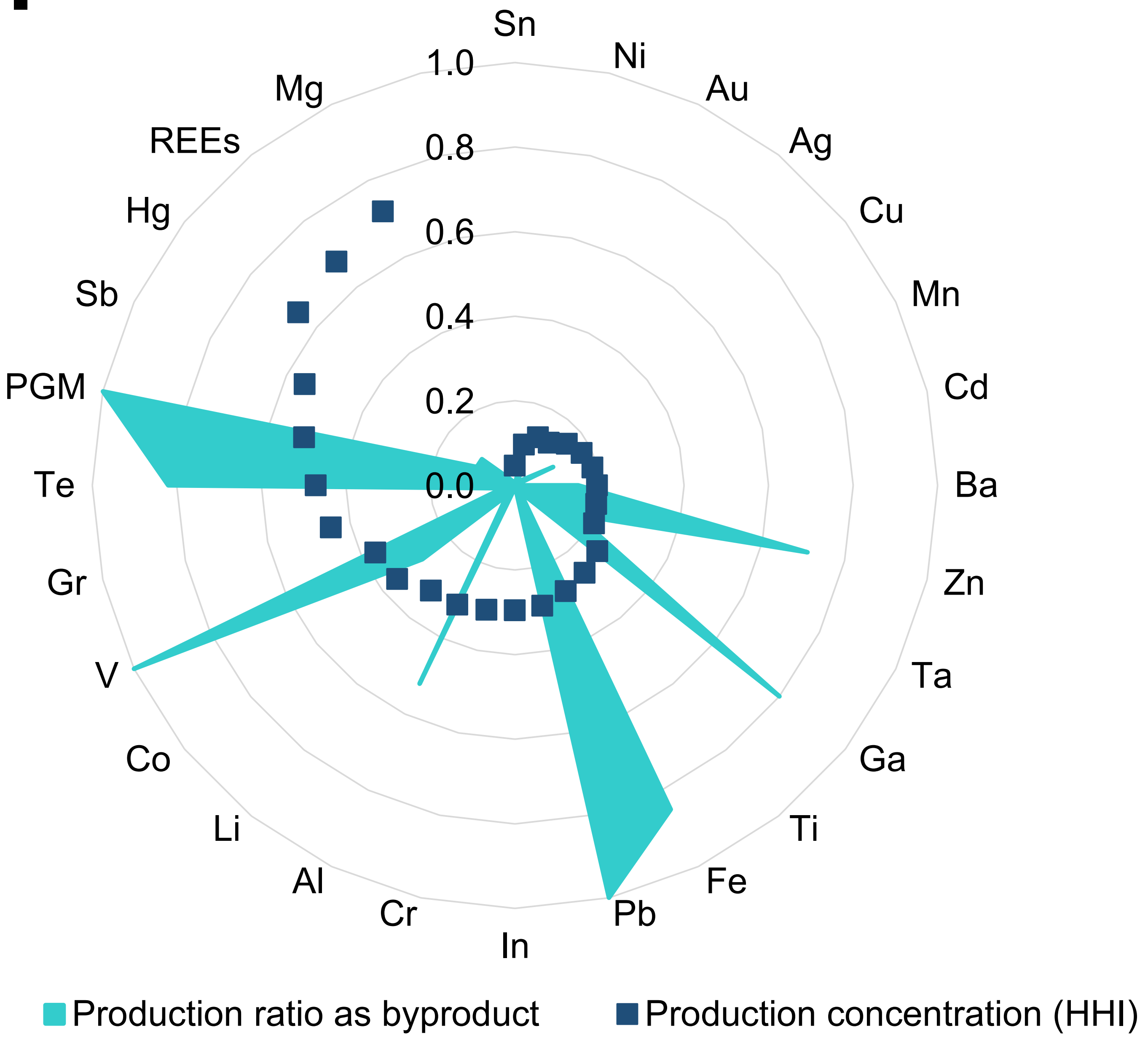
Citation:
Althaf, S., Babbitt, C.W. Madaka, H., Gaustad, G., Flynn, C. 2019. “Sustainable Materials Management Metrics to Assess Consumer Technology – Phase 3: Development and application of sustainability metrics to identify environmental, economic, and social issues and opportunities for materials used in technology products.” A report to the Staples Sustainable Innovation Lab and the Consumer Technology Association.

Electronics materials have concentrated supply chains



Althaf et al. 2019

Supply chains are vulnerable to geopolitical and market disruptions



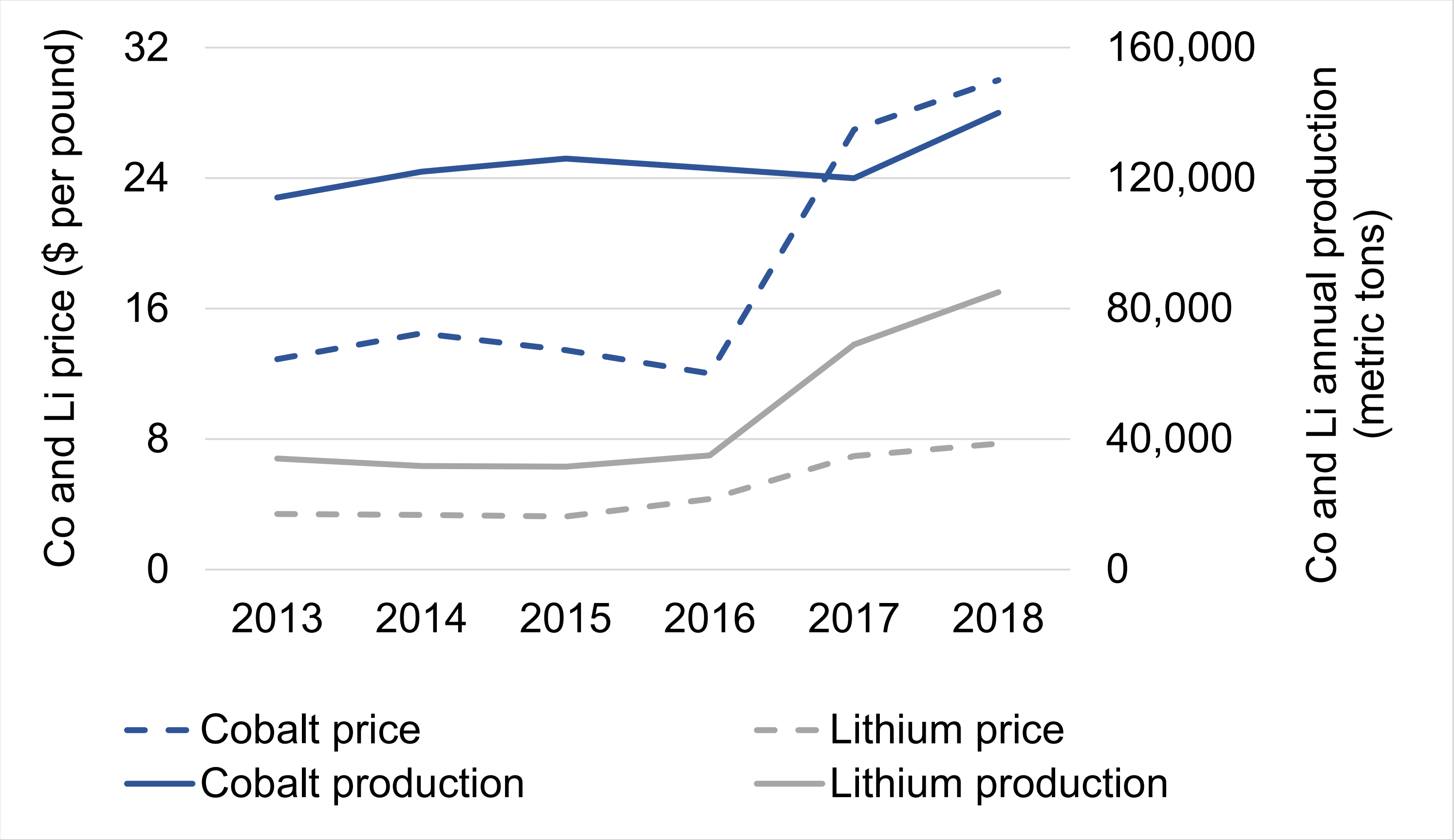
Althaf et al.
2019

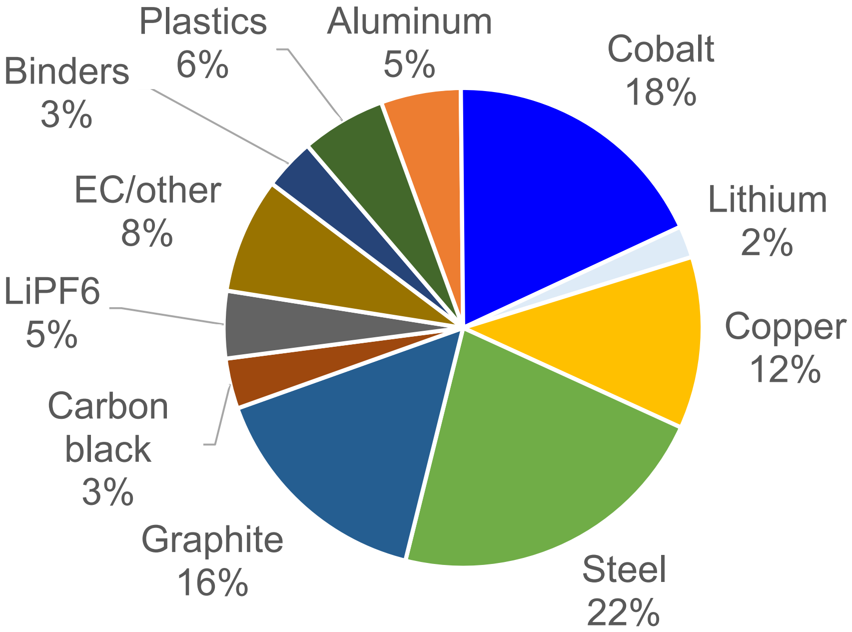
Future availability faces competition from other sectors

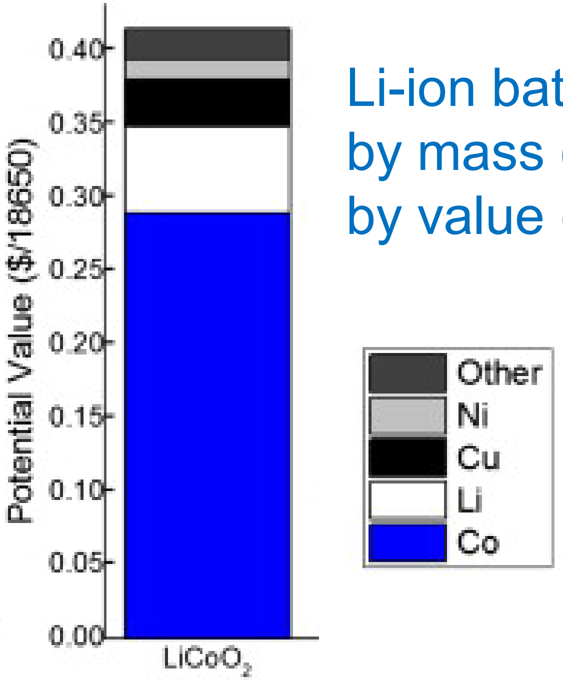
Material Hotspots		Annual U.S Consumption (metric tons)	Main Use Sector in US	Consumption in electronics sector
Precious metals	Au	145	Jewelry	6%
	Ag	5,500	Electrical and electronics	25%
	Pd	42	Auto catalysts	45%
	Pt	45	Auto catalysts	68%
Critical/ strategic metals	Co	7,200	Superalloys in aircraft engines	22%
	Ga	23,000	Integrated Chips	67%
	In	170	ITO layer in flat panel displays	84%
	Li	2,000	Batteries	46%
	Ta	1,170	Tantalum capacitors	48%
	Sn	46,000	Tinplate, solder	48%
Rare Earth Elements (REEs)		12,200	Catalysts	75% ++

Althaf et al. 2019

Example: battery materials



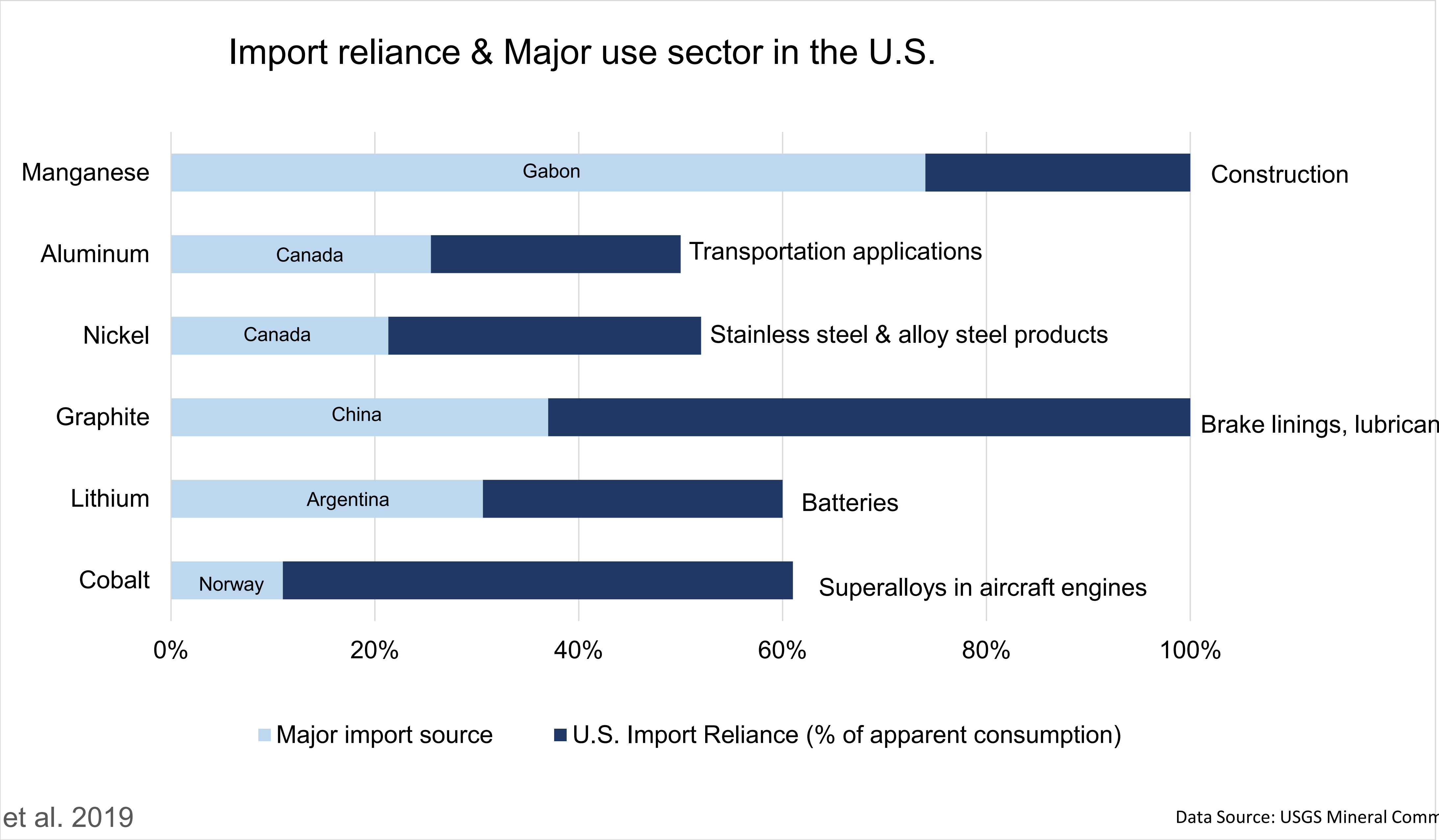




Li-ion battery content, by mass (above) and by value (below)

Althaf et al. 2019; Wang et al. 2014

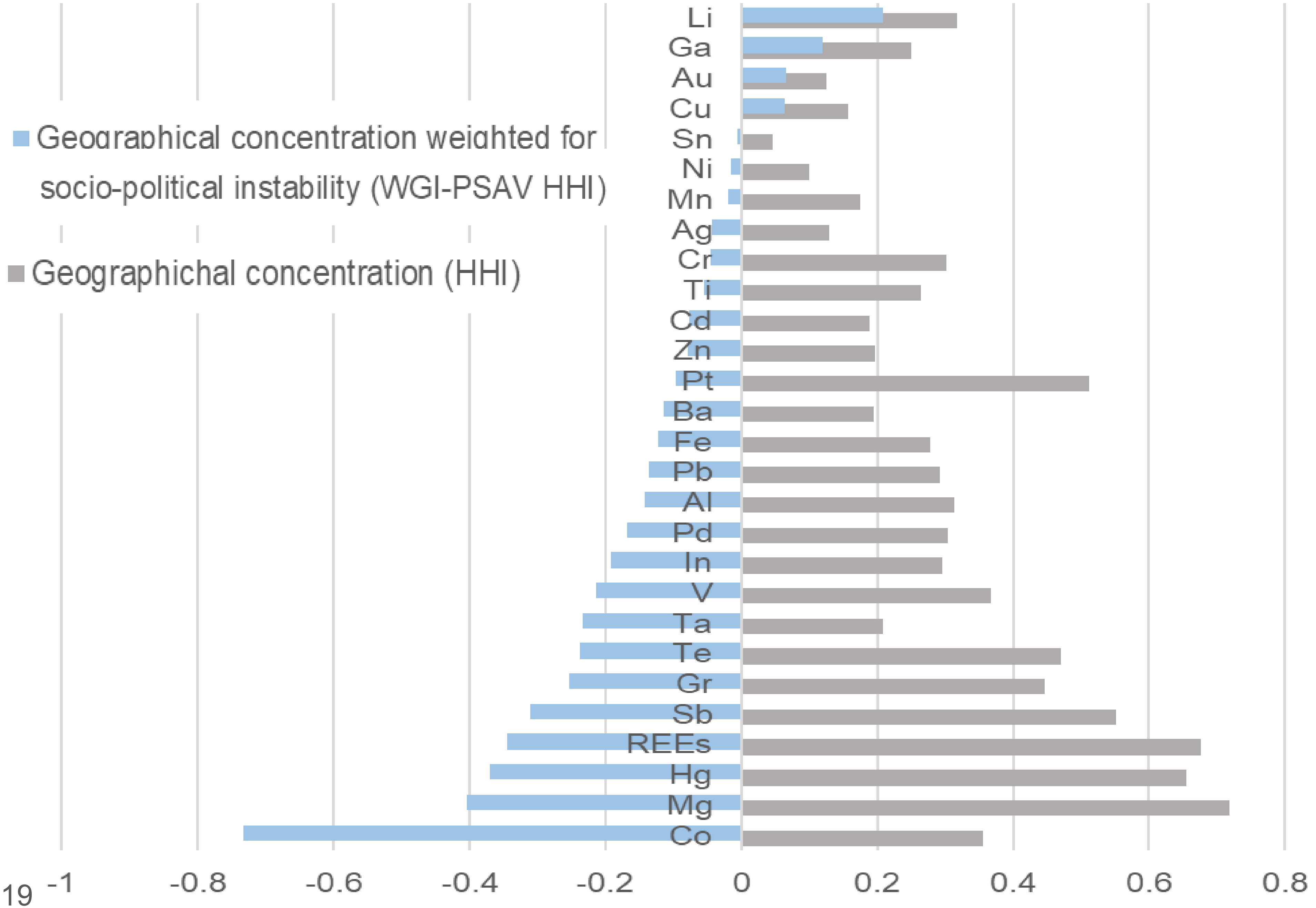
Example: battery materials



Althaf et al. 2019

Data Source: USGS Mineral Commodity Summaries

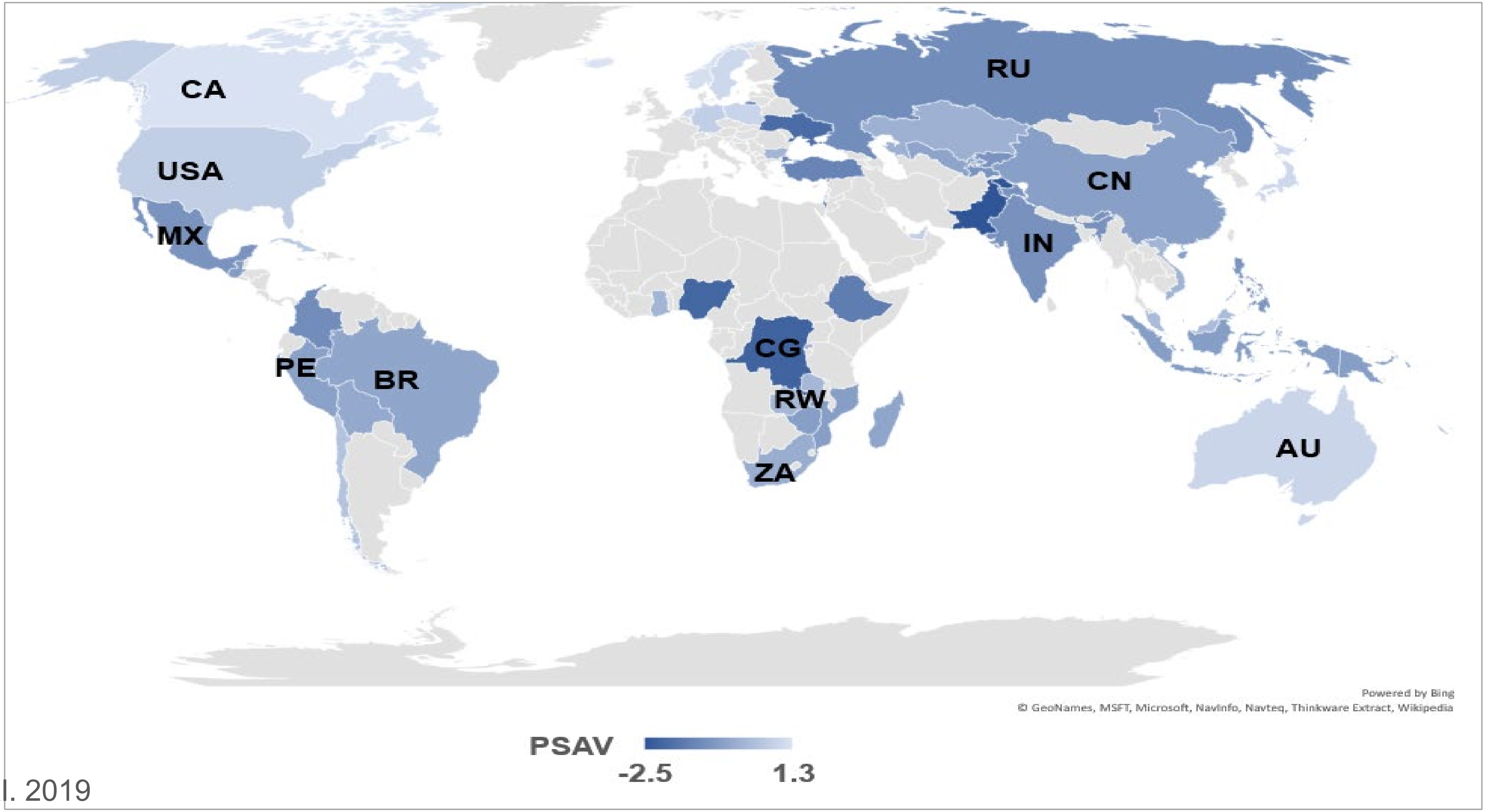
Supply chains face social vulnerability



Althaf et al. 2019

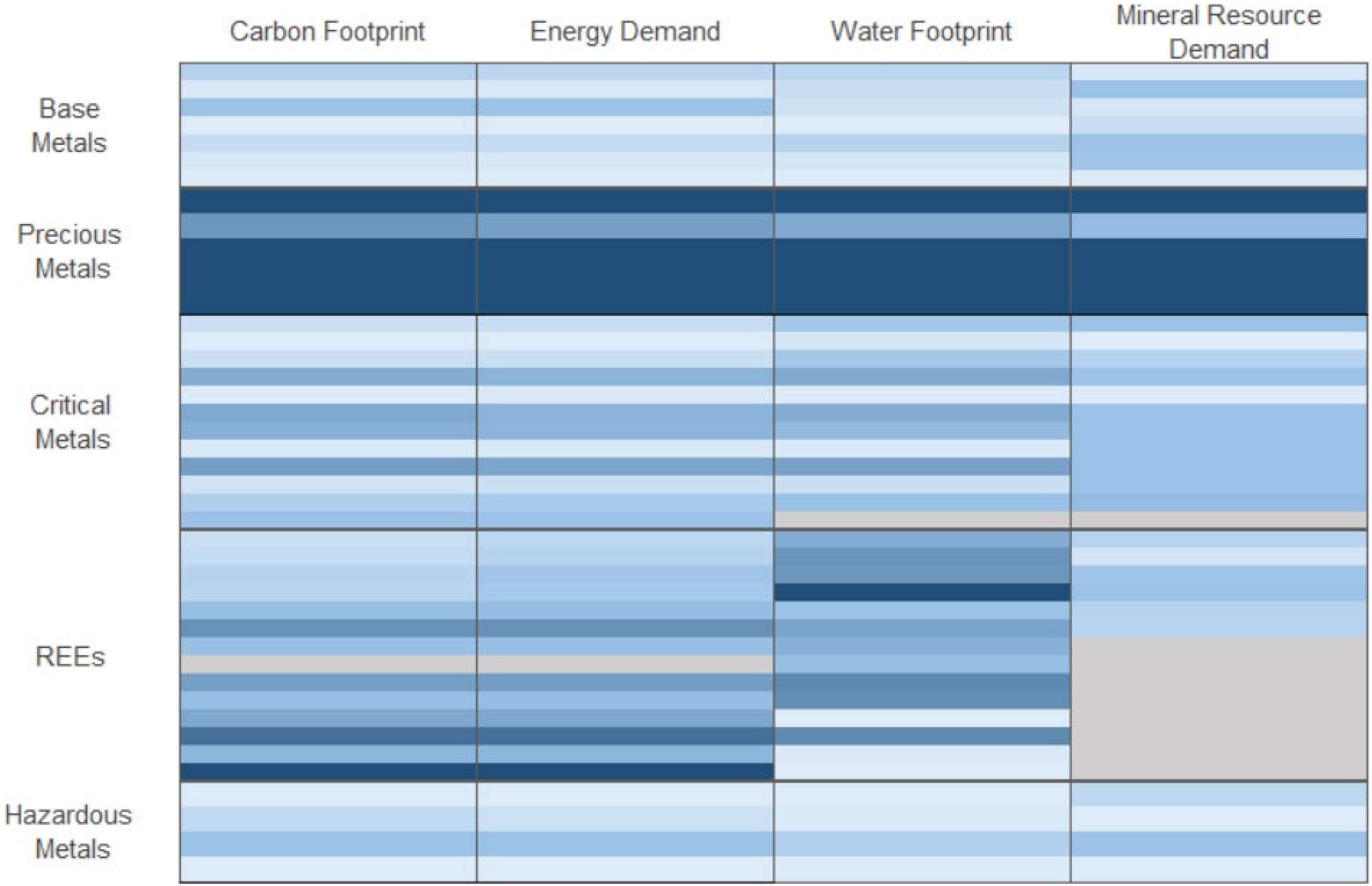
Social vulnerabilities vary with supply chain geopraphy

Political stability and absence of violence in major producing regions



Althaf et al. 2019

Material extraction and processing create variable environmental impacts

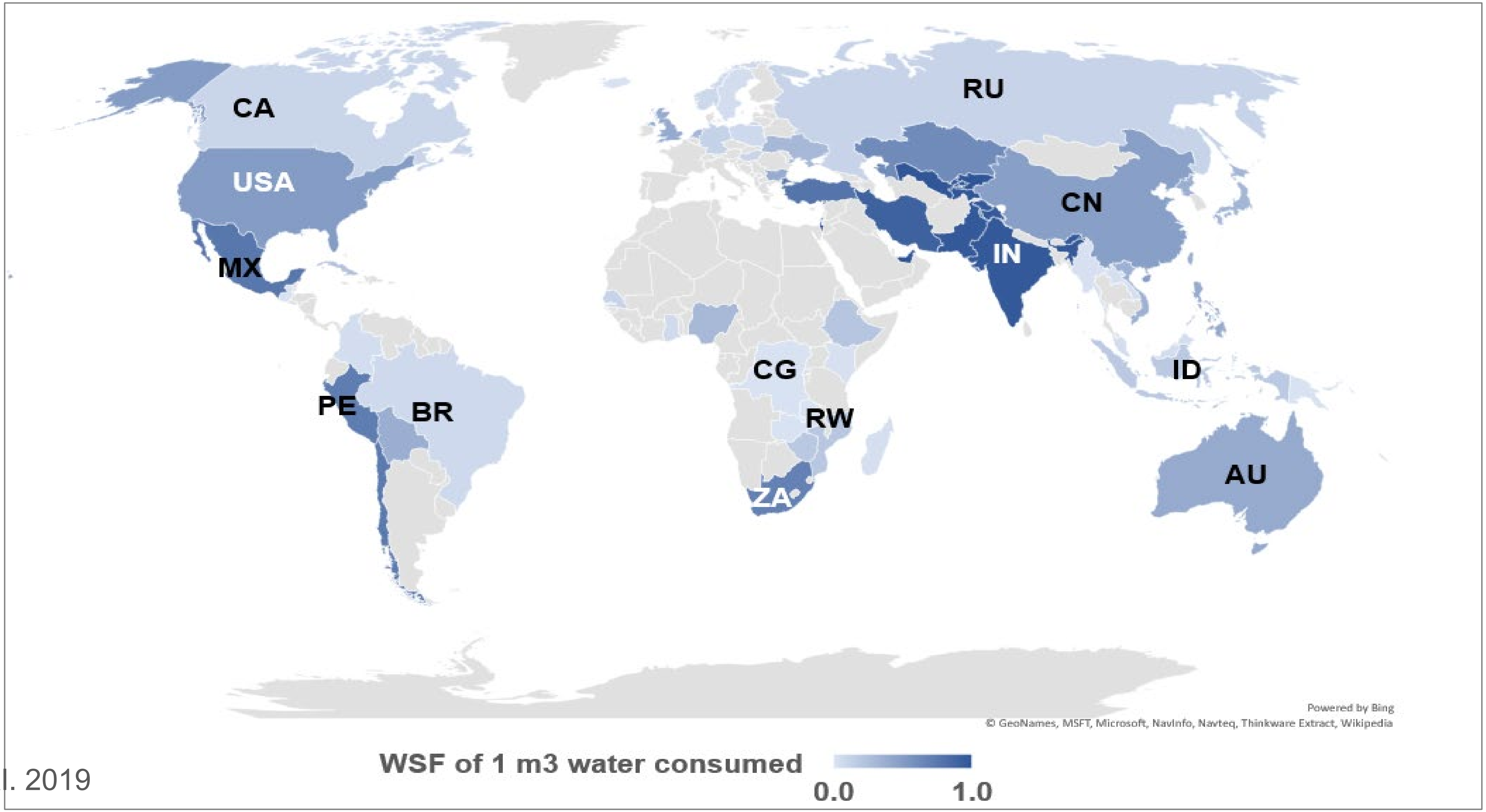


Results are shown on "per kg" basis

Althaf et al. 2019

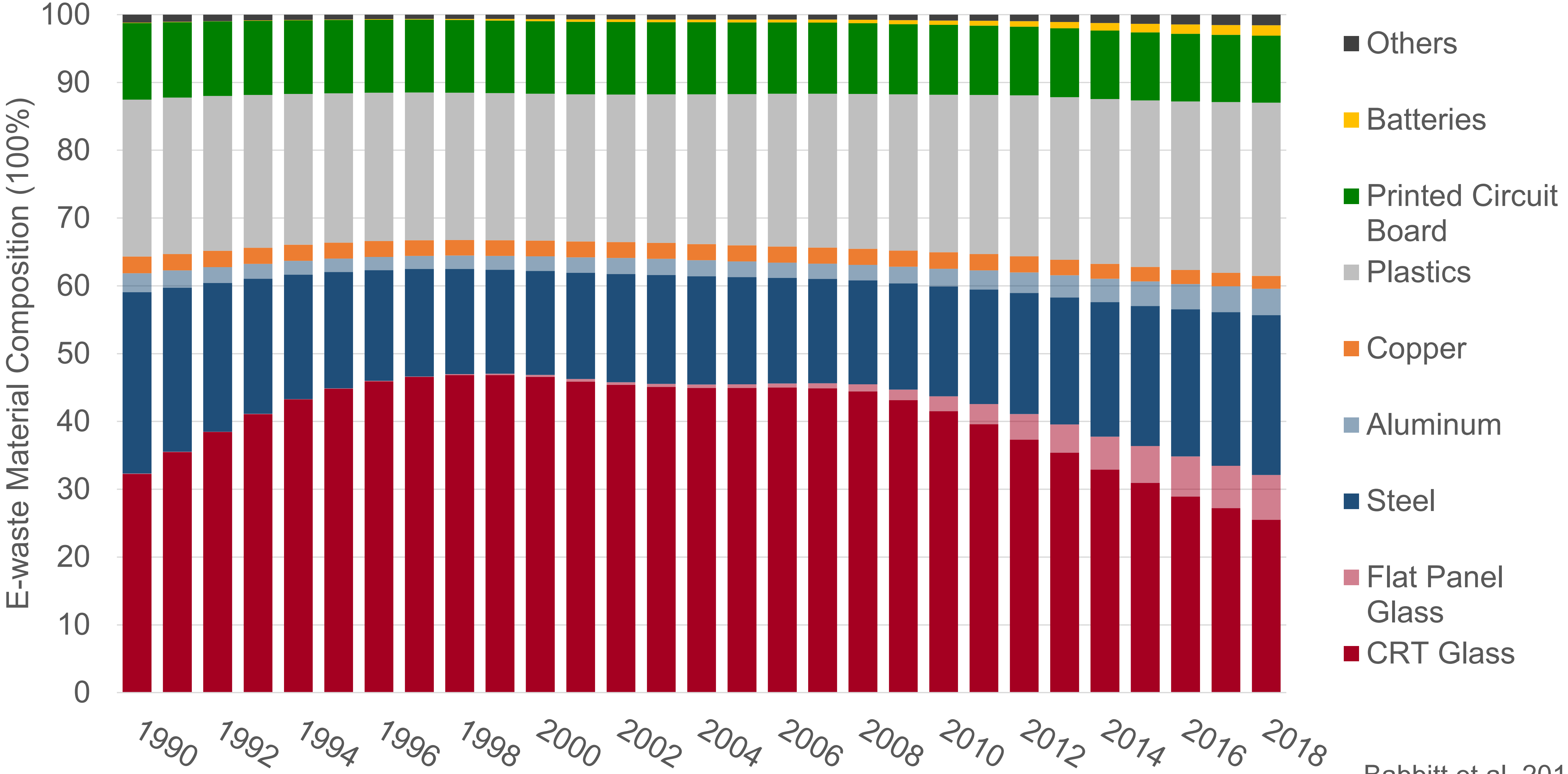
Environmental impacts vary with supply chain geography

Water scarcity footprint: considers amount of water used and scarcity in region of use



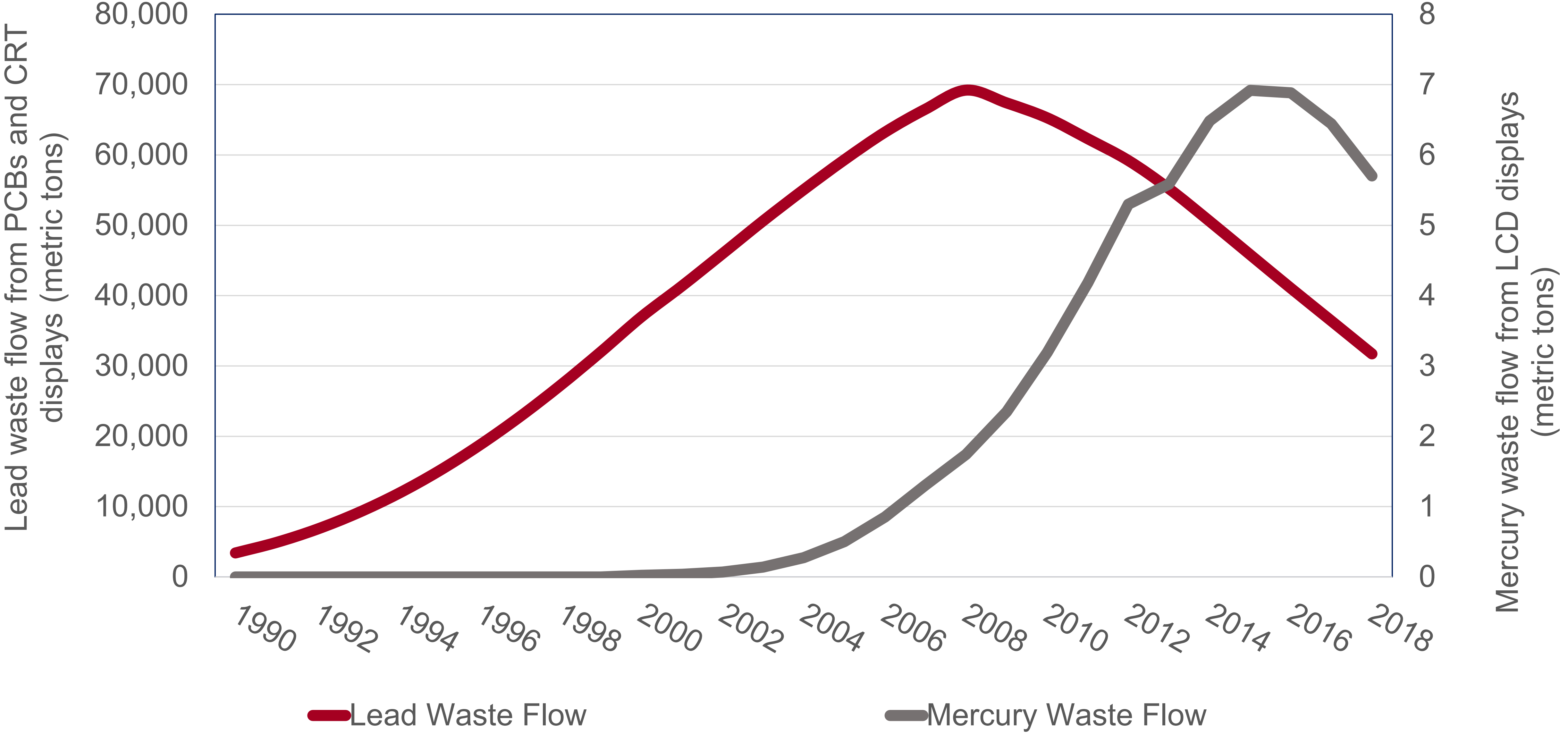
Althaf et al. 2019

End-of-life management faces an evolving material mix



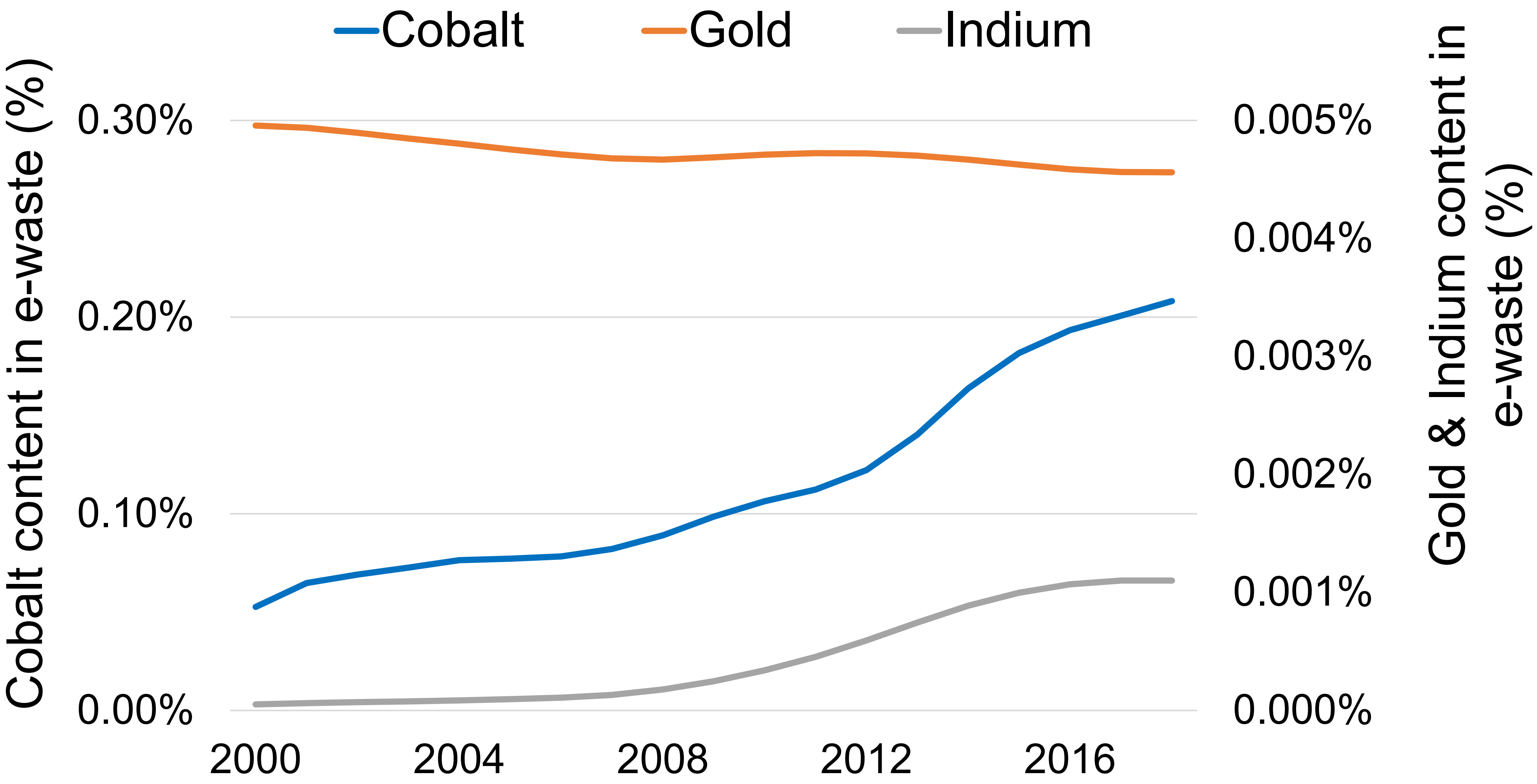
Babbitt et al. 2017

Traditional material hazards have begun to decline



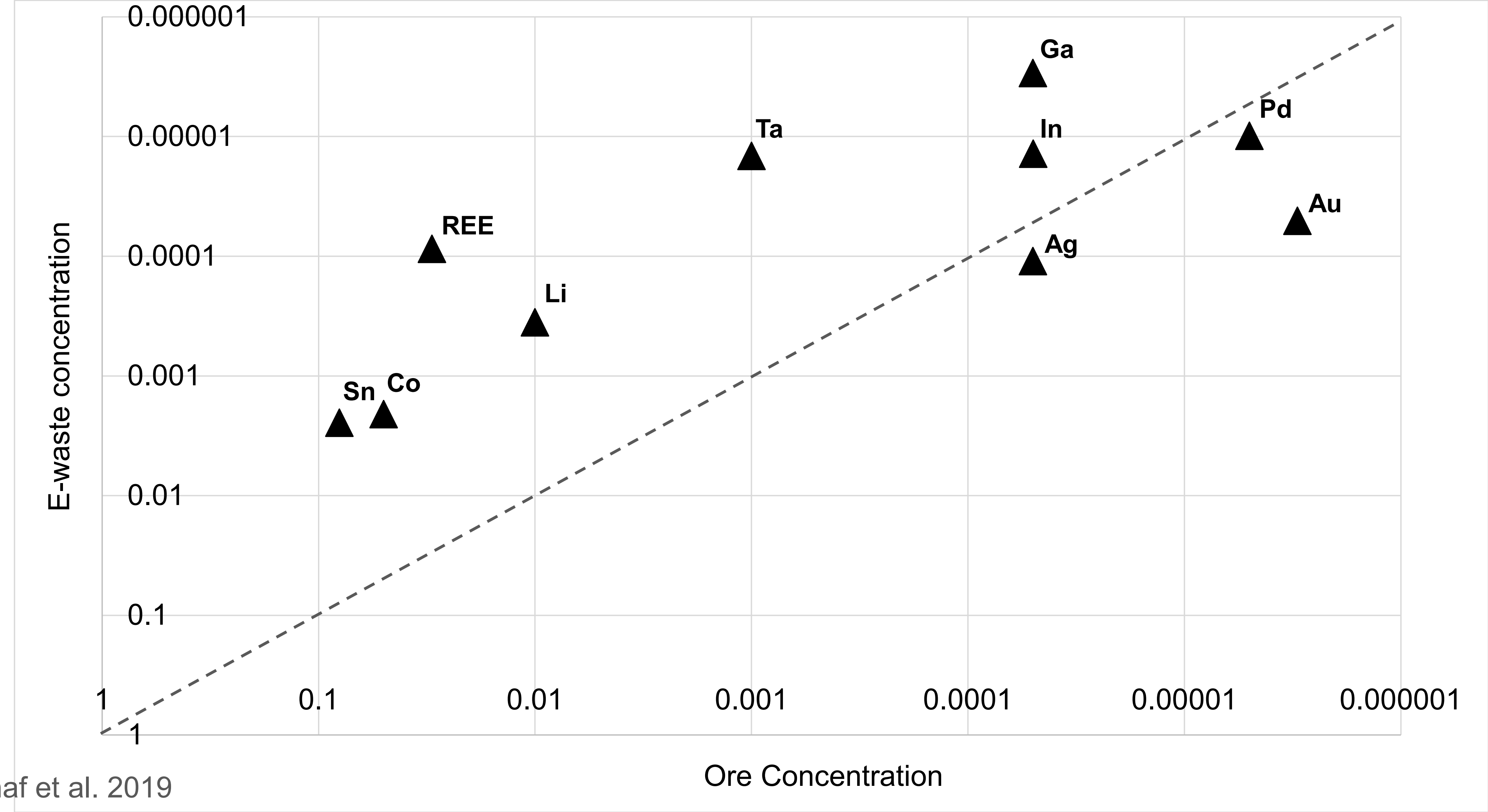
Babbitt et al. 2017

Material recovery opportunities are changing



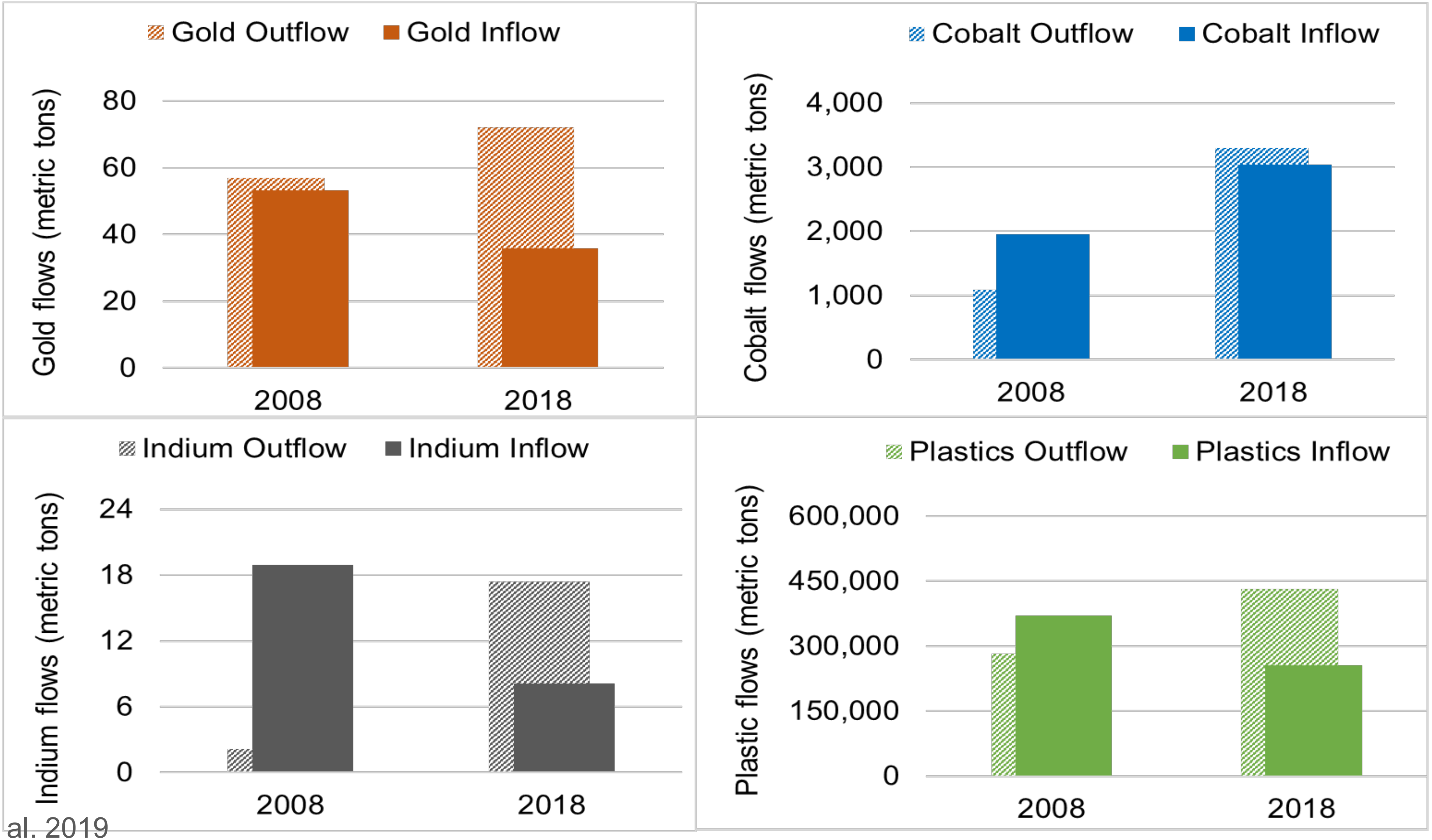
Babbitt et al. 2017, Althaf et al. 2019

Elemental concentration in e-waste is relatively low, but recovery alleviates supply chain risks



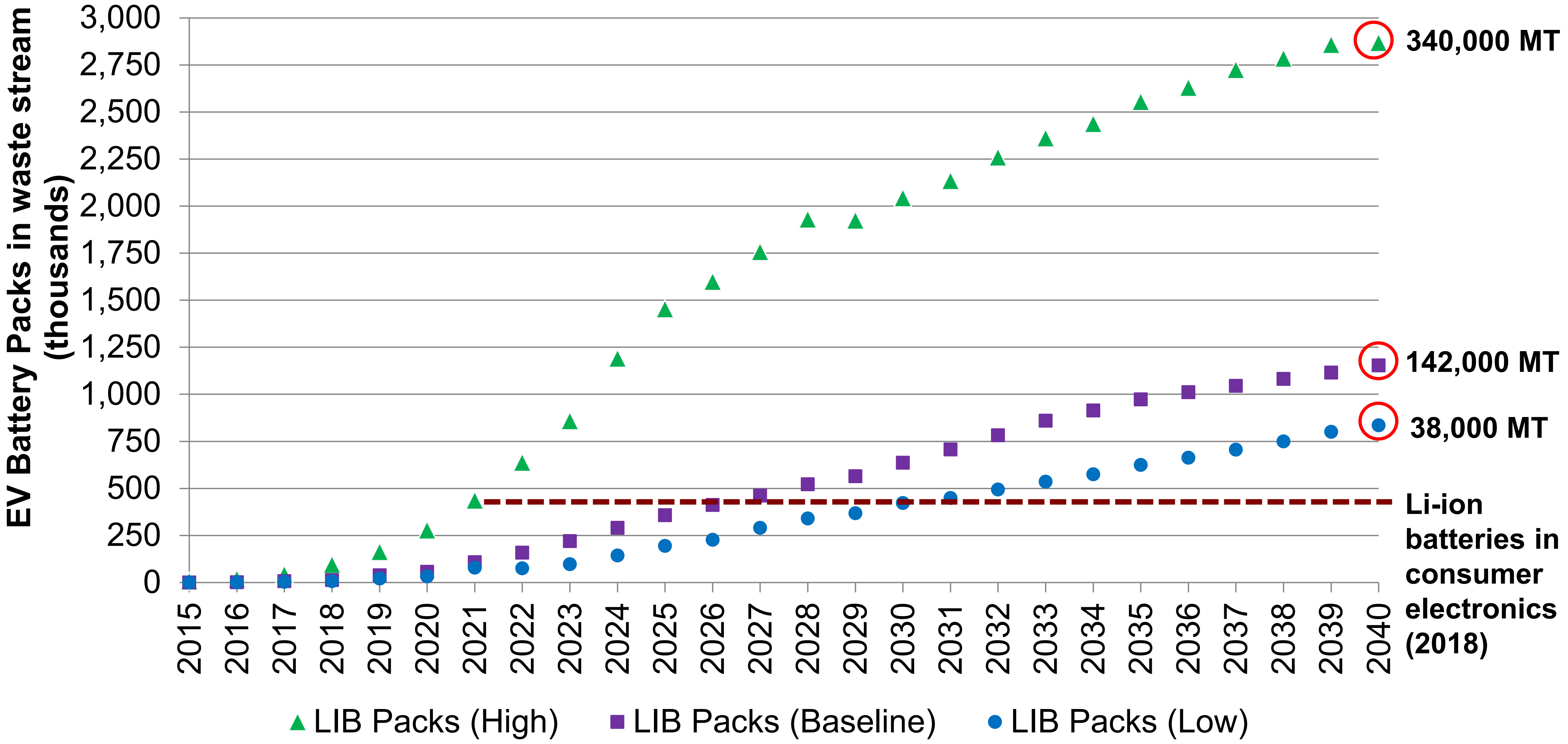
Althaf et al. 2019

"Closed loop" is theoretically feasible, but limited by form, technology, and markets



Althaf et al. 2019

Recovery also influenced by competing sectors: battery example



Richa et al. 2014

Next Steps and Needed Input

Stakeholder-driven material exploration

- Battery materials – alternate technologies, recycling innovations
- Plastics – bio-based, recycled content, recycling, water impacts

**New research project funded on Circular Economy and plastics – looking for industry input

Research on e-plastic degradation, flame retardants

Contact and Acknowledgements

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Reports available at:
http://www.rit.edu/gis/ssil/reports.php

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